United States Court of Appeals
for the
District of Columbia Circuit

TRANSCRIPT OF RECORD

No. 10,631

JOINT APPENDIX TO BRIEFS

United States Court of Appeals

FOR THE DISTRICT OF COLUMBIA CIRCUIT

United States Court of A
For the
District of Columbia Cir

FILED AUG 31 1950

CLERK

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NEIL O. BRODERSON, *Appell*[illegible]

vs.

JOHN A. MARZALL, Commissioner of Patents, *Appellee.*

Appeal from the United States District Court for the District of Columbia

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United States Court of Appeals

For the District of Columbia Circuit

No. 10,631

Neil O. Broderson, *Appellant,*

vs.

John A. Marzall, Commissioner of Patents, *Appellee.*

Appeal from the United States District Court
for the District of Columbia

JOINT APPENDIX TO BRIEFS

140 Filed Nov 25 1947 Harry M. Hull, Clerk

IN THE DISTRICT COURT OF THE
UNITED STATES FOR THE
DISTRICT OF COLUMBIA
Civil Action No.
4789 - '47
NEIL O. BRODERSON,
72 Penfield Road,
Rochester, New York,
Plaintiff,
v.
LAWRENCE C. KINGSLAND,
Commissioner of Patents,
Washington, D. C.
Defendant.

Complaint

To the Honorable Judges of the District Court of the United States for the District of Columbia:

The plaintiff, for his complaint, alleges:

1.

That the jurisdiction of this Court depends upon the Statutes of the United States relating to the grant and issuance of Letters Patent of the United States, and particularly upon that section thereof known as Sec. 4915 R. S.; U. S. C., title 35, sec. 63.

2.

That plaintiff, Neil O. Broderson, is a citizen of the United States, residing at 72 Penfield Road, Rochester, New York.

3.

That defendant, Lawrence C. Kingsland, is the Commissioner of Patents of the United States, whose official residence as Commissioner of Patents is in the District of Columbia, and he is sued as Commissioner of Patents of the United States.

141 4.

That plaintiff did invent certain new and useful improvements in Method of Operating Internal Combustion Engines, for which invention an application for Letters Patent of the United States was filed in the United States Patent Office on May 13, 1942, entitled "Method of Operating Internal Combustion Engines", which application was given the Serial No. 442,830, being a continuation-in-part of a prior application for Letters Patent of the United States on said invention filed in the United States Patent Office by plaintiff on February 21, 1940 and given the Serial No. 320,208.

5.

That said application was filed and has been duly prosecuted in accordance with the Laws of the United States and the Rules of Practice of the Patent Office.

6.

That a patent on the said application has been refused by the Commissioner of Patents, defendant herein.

7.

That the invention involved in this proceeding relates to a method of operating internal combustion engines comprising admitting air to the combustion chamber of the engine and compressing the air within the combustion chamber, injecting into an auxiliary combustion zone communicating with and forming part of the combustion chamber controlled charges of fuel increasing in amount with increasing power demand upon the engine during a controlled period of time comprised between the beginning of induction and the completion of compres-
142 sion, effecting a differential distribution of the fuel

between the auxiliary combustion zone and the remaining portion of the combustion chamber to provide in the auxiliary combustion zone an ignitable fuel mixture at the time of ignition under all conditions of power demand, and igniting the mixture under compresson in the auxiliary combustion zone.

8.

The said application has been passed upon by the Primary Examiner who refused to allow any of the claims of said application, and that the Primary Examiner finally rejected the following claims:

1. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and
to provide in the auxiliary combustion chamber at
143 the time of ignition an ignitable fuel mixture under
all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mxture under compression in the auxiliary combustion chamber.

2. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine

including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture and in the main combustion chamber a fuel mixture outside the critical detonating range under all conditions of power demand, and igniting the mixture under compression in the auxiliary combustion chamber.

144 3. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main

combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

4. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture and in the main combustion chamber a fuel mixture outside the critical detonating range under all conditions of power demand, and igniting the mixture under compression in the auxiliary combustion chamber.

5. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume from 0.1 to 0.5 the volume of the total combustion space at top center posi-

tion of the piston, compressing the air within the
146 combustion chambers, supplying to the combustion
chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

6. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, injecting into the auxiliary combustion chamber controlled charged of fuel varied in timing and duration with respect to power demand upon the engine, at least a portion of said fuel charges
being injected during the compression stroke in an
147 amount varied in predetermined relation to the total
quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion

chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

7. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and and auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount with respect to the relative sizes of the auxiliary and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable
148 mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

8. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during
the compression stroke of the piston controlled
149 portions of said charges of fuel varied in amount
with respect to the relative sizes of the auxiliary
and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

9. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having
150 a volume not substantially exceeding the volume of
the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, injecting into the auxiliary combustion chamber controlled charges of fuel varied in timing and duration with respect to power demand upon the engine, at least a portion of said fuel charges being injected during the compression stroke in an amount varied with respect to the relative sizes of the auxiliary and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

151 9.

That from the decision of the Primary Examiner an appeal was taken to the Board of Appeals of the United States Patent Office which affirmed the rejection of the Primary examiner in its decisions dated May 26, 1947 and June 30, 1947; and that no appeal has been taken to the United States Court of Customs and Patent Appeals from said decisions.

10.

That the invention is new and useful, and was not known or used by others in this country before the invention thereof by plaintiff, and was not patented or described in any printed publication in this or any country before the invention thereof by plaintiff or more than one year prior to his said application for patent therefor, and was not in public use or on sale in the United States for more than one year prior to said application, and was not patented in any country foreign to the United States on an application filed by plaintiff or his legal representatives or assigns more than twelve months prior to said application for United States Letters Patent and has not been abandoned.

WHEREFORE, the plaintiff prays this Honorable Court:

I. To adjudge that plaintiff is entitled according to law to receive Letters Patent of the United States for the aforesaid invention as defined in claims 1 to 9 hereinbefore recited.

II. To decree that the Commissioner of Patents be directed to allow the aforesaid claims 1 to 9 and such other claims as upon hearing the Court may find patentable, and to issue to plaintiff United States Letters Patent containing said claims.

152 III. For such other and further relief as the nature of the case may require.

NEIL O. BRODERSON
By /s/ Harold T. Stowell
Harold T. Stowell

/s/ John O. Evans, Jr.
John O. Evans, Jr.
Attorneys for Plaintiff
1420 New York Ave., N. W.
Washington 5, D. C.
Phone: National 6856

153 Filed Jan 17 1948 Harry M. Hull, Clerk

* * * *

Answer to the Complaint.

To the Honorable the Justices of the District Court of the United States for the District of Columbia.

1, 2, 3. Defendant admits the allegations of paragraphs 1, 2 and 3.

4. He admits that on May 13, 1942, plaintiff, claiming to be the inventor of certain alleged new and useful improvements in the Method of Operating Internal Combustion Engines, filed in the Patent Office an application for patent thereon, to which application Serial No. 442,830 was given. He admits that said application was filed as a continuation-in-part of an earlier application of plaintiff, Serial No. 320,208, which was filed in the Patent Office on February 21, 1940. He denies, for reasons hereinafter given, that the subject matter claimed in plaintiff's application No. 442,830 constitutes a patentable invention.

5, 6. He admits the allegations of paragraphs 5 and 6.

154 7. He admits that paragraph 7 sets forth the general nature of plaintiff's alleged invention but states that plaintiff is entitled to rely only on the claims of his application No. 442,830 for a statement of his alleged invention. Defendant denies, for reasons hereinafter given, that the subject matter claimed in said application No. 442,830 constitutes a patentable invention.

8, 9. He admits the allegations of paragraphs 8 and 9.

10. He admits that plaintiff in his application, Serial No. 442,830, made averments corresponding to the allegations of paragraph 10, but denies that said allegations are sufficient to justify the issuance of a patent on said application containing any one of claims 1 to 9, inclusive, thereof. He states that the said claims are unpatentable in view of the following prior patents and for the reasons given in the Examiner's statement and in the decisions rendered by the Board of Appeals on May 26, 1947, and June 30, 1947, copies of which will be furnished at the trial:

Yost et al.,	1,096,585,	May 12, 1914,
Power,	1,235,725,	Aug. 7, 1917,
Werner,	1,616,157,	Feb. 1, 1927,
Hesselman,	1,835,490,	Dec. 8, 1931,
Wild et al.,	2,005,063,	June 18, 1935,
Starr,	2,025,362,	Dec. 24, 1935,
Bremser,	2,061,826,	Nov. 24, 1936,
Mock,	2,142,280,	Jan. 3, 1939,
Dillstrom,	2,145,250,	Jan. 31, 1939,
Chapman,	2,204,068,	June 11, 1940,
British patent,	195,609,	Jan. 31, 1924,
“ “	373,647,	May 17, 1932
Swiss patent,	208,611,	May 16, 1940.

Profert of copies of these patents is hereby made.

/s/ W. W. Cochran
Solicitor, U. S. Patent Office,
Attorney for Defendant.

155 January 16, 1948.

I hereby certify that a copy of this ANSWER TO THE COMPLAINT was mailed today, January 16, 1948, to the attorneys for plaintiff, Messrs. Harold T. Stowell and John O. Evans, 1420 New York Ave., N. W., Washington 5, D. C.

/s/ W. W. Cochran
Solicitor.

156 Filed Dec 7 1949 Harry M. Hull, Clerk

* * * *

Order.

Upon consideration of the fact that John A. Marzell succeeded to the office of Commissioner of Patents on December 2, 1949, in place of Lawrence C. Kingsland, who resigned, and it appearing that there is substantial need for continuing and maintaining the above-entitled action, now therefore it is this 7th day of December 1949

ORDERED that John A. Marzall, Commissioner of Patents be and he is hereby substituted as party defendant in place of Lawrence C. Kingsland, formerly Commissioner of Patents.

H. A. Schweinhaut
Judge.

* * * *

157 Filed Jan 4 1950 Harry M. Hull, Clerk

Opinion of Court

Plaintiff seeks to have the Court authorize the Commissioner of Patents to issue a patent to him on certain claims which have been rejected by the Patent Office.

Claim 1 is illustrative and reads as follows:

1. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined

relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

The claims are directed to a method of operating a four-cycle internal combustion engine. This engine is operated with a main combustion chamber defined as located between the top of the piston in its uppermost position and the cylinder head and an auxiliary combustion chamber, the volume of which is not substantially larger than that of the main combustion chamber and is separated from it by slight restriction; a fuel and an 158 igniter are located in the auxiliary combustion chamber. A part of the total fuel supplied for each stroke may be separately injected into the auxiliary combustion chamber during the compression stroke of the piston, the remaining portion being injected during the induction or suction stroke. When the engine is being operated constant charges of air are admitted into the combustion chamber during the suction stroke. A portion of the fuel injected during the suction stroke may be brought in with the charge of air. By control of the time and proportion of fuel injected the plaintiff alleges that detonation and knocking is avoided.

The Patent Office rejected the plaintiff's claims upon several patents but relied chiefly upon the patents to Mock 2,142,280, Werner 1,616,157, and a British patent 373,647.

The patent to Mock discloses a four-cycle internal combustion engine including a main combustion chamber formed between the top of the piston at its upper most position and the cylinder head with a restriction between the main combustion chamber and an auxiliary combustion chamber. The fuel is injected into the auxiliary combustion chamber, a portion of it during the combustion stroke, and the remainder just prior to ignition. The only real difference in the methods of the Mock patent and plaintiff's application is the structural limitation in the latter to the effect that the volume of the auxiliary chamber does not exceed the volume of the main combustion chamber at top center of the piston, while in Mock the auxiliary chamber is much larger than the combustion chamber.

The Werner patent discloses an internal combustion engine which combines the Otto cycle and the Diesel cycle operation—a four-stroke cycle. The engine includes a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and the volume of the auxiliary combustion chamber is smaller than the volume of the main combustion chamber at top center position of the piston.

159 I agree with the Board of Appeals of the Patent Office that no invention is shown by the plaintiff in view of the prior art. Nor do I think that the testimony introduced at the trial in any way affects the conclusion reached by the Board of Appeals.

The complaint will be dismissed.

Jennings Bailey
Judge

* * * *

160 Filed Jan 30 1950 Harry M. Hull, Clerk

Findings of Fact

1. This is a suit brought under the provisions of Section 4915 R. S. (35 U. S. C. 63) in which it was sought to have the Court find that plaintiff, Neil O. Broderson, who, on May 13, 1942, filed an application for patent, Serial No. 442,830, is entitled to have a patent issued to

him containing claims 1 to 9, inclusive, of that application.

2. In accordance with the disclosure of plaintiff's application, the claims in suit are directed to a method of operating a four-cycle internal combustion engine. The engine so operated includes a main combustion chamber, defined as located between the top of the piston in its uppermost position and the bottom of the cylinder head, and an auxiliary combustion chamber. The volume of the auxiliary combustion chamber is not substantially larger than the volume of the main combustion chamber, and the auxiliary combustion chamber is separated from the main combustion chamber by a slight restriction. A fuel injection nozzle and an igniter are located in the auxiliary combustion chamber. All, or a part, of the total fuel supplied during one complete cycle of operation of the engine is injected into the auxiliary combustion chamber durinug the compression stroke of the piston, the re-
161 maining portion being injected during the induction
or suction stroke. In the operation of the engine, constant charges of air are admitted during the suction stroke into the entire combustion space, which includes the main combustion chamber and the auxiliary combustion chamber. A portion of the fuel injected during the suction stroke may be brought in with the charges of air. By controlling the timing and proportioning the injection of fuel during the suction and compression strokes, plaintiff alleges that detonation and knocking are avoided.

3. In the Patent Office, the claims in suit were rejected upon several patents. In refusing these claims to plaintiff, the Board of Appeals relied chiefly upon the United States patent to Mock, No. 2,142,280, granted January 3, 1939; the United States patent to Werner, No. 1,616,157, granted February 1, 1927; and British patent, No. 373,647, dated May 17, 1932. At the trial, defendant likewise placed chief reliance upon these same three patents.

4. The patent to Mock discloses a four-cycle internal

combustion engine having a main combustion chamber, formed between the top of the piston at its uppermost position and the bottom of the cylinder head, and an auxiliary combustion chamber communicating therewith through a restricted passage. The auxiliary combustion chamber is shown as much larger than said main combustion chamber. The fuel is injected into the auxiliary combustion chamber, a portion of it during the intake or suction stroke and the remainder during the compression stroke and just prior to ignition. The only real difference between the method disclosed in the Mock patent and that expressed in plaintiff's claims in suit resides in the structural limitation in the claims to the effect that the volume of the auxiliary chamber does not exceed the volume
162 of the main combustion chamber at top center position of the piston.

5. No invention is shown by plaintiff in applying the process disclosed in the Mock patent to an engine in which the auxiliary combustion chamber is not larger in volume than the main combustion chamber, particularly in view of British patent, No. 373,647, and also of the Werner patent, each of which discloses a main combustion chamber and an auxiliary combustion chamber that are so related as to volume.

6. The Werner patent discloses an internal combustion engine which combines Otto cycle and Diesel cycle operation, and operates through a four-stroke cycle. The larger, and main, combustion chamber is in constant communication with the smaller, and auxiliary, combustion chamber through a restricted passageway. An injector sprays fuel into the main combustion chamber, and either a carburetor or an auxiliary injector introduces fuel into the auxiliary combustion chamber, to supply charges of fuel varied in amount. Werner, in his patent, specifies that a small portion of the fuel can be injected into the auxiliary combustion chamber during and toward the end of the compression stroke.

7. With respect to the four-cycle engine disclosed in the Werner patent, variation of the amount of fuel injected at the various parts of the cycle for the purpose of avoiding detonation is a mere matter of adjustment well within the scope of knowledge of the skilled mechanic.

8. Plaintiff's claims in suit are unpatentable in view of the United States patents to Mock and Werner and British patent, No. 373,647.

9. The testimony introduced at the trial does not in any way affect the conclusion reached by the Board of Appeals as to the unpatentability of plaintiff's claims in suit.

163 *Conclusions of Law*

1. Plaintiff is not entitled to a patent containing any of claims 1 to 9, inclusive, of his application in suit.

2. The complaint should be dismissed as to all the claims in suit.

Jennings Bailey
Judge

January 30th, 1950.

* * * *

164 Filed Jan 30 1950 Harry M. Hull, Clerk

Judgment

This action came on to be heard at the last term, and thereupon upon consideration thereof, it is this 30th day of January, 1950

ADJUDGED that the complaint be and it is hereby dismissed, with costs against plaintiff.

Jennings Bailey
Judge

* * * *

165 Filed Mar 29 1950 Harry M. Hull, Clerk

Notice of Appeal

Notice is hereby given that Neil O. Broderson, plaintiff above named, appeals to the United States Court of Appeals for the District of Columbia from the final judgment entered in this action on January 30, 1950.

/s/ Harold T. Stowell
Harold T. Stowell
Attorney for Neil O. Broderson,
Appellant
Warner Building
Washington 4, D. C.

* * * *

2 *Proceedings*

THE DEPUTY CLERK OF THE COURT: Broderson v. Kingsland.

THE COURT: Who is Mr. Bean?

MR. BEAN: I am Mr. Bean, Your Honor, and this is Mr. Stowell, and Mr. Broderson.

THE COURT: Have you the usual paper from the Patent Office?

MR. MOORE: Yes, Your Honor. With the consent and agreement of counsel for the plaintiff, I would like to introduce this booklet of patents in evidence now, out of order, as defendant's sole exhibit.

THE COURT: Is there any objection to that?

MR. BEAN: No objection, Your Honor.

THE COURT: It will be admitted. It will simplify matters.

(Thereupon the document was received in evidence and marked Defendant's Exhibit No. 1.)

MR. BEAN: Your Honor, with the consent of Mr. Moore I would like to offer in evidence as Plaintiff's Exhibit No. 1 a certified copy of the file wrapper and contents of the pending application of Neil Broderson, serial number 442,830. This contains the specifications and drawings and all the proceedings to date in the Patent Office.

MR. MOORE: No objection, Your Honor.

THE COURT: Very well. It will be admitted.

3 (Thereupon the document was received in evidence and marked Plaintiff's Exhibit No. 1.)

MR. BEAN: May I make a brief opening statement?

THE COURT: Yes.

* * * *

24 *Sven Rolfsen, Jr.,*

was called as a witness by the plaintiff, and, being first duly sworn, was examined and testified as follows:

THE DEPUTY CLERK OF THE COURT: What is your full name?

THE WITNESS: Sven Rolfsen, Jr.

Direct Examination

BY MR. BEAN:

Q Mr. Rolfsen, will you state your residence address and your employment? A Well, I live at 2586 Brown Grove Boulevard, Rochester, New York, and I am a mechanical engineer employed by Mr. Broderson.

Q You are a mechanical engineer employed by Mr. Broderson? A Yes, sir.

Q Will you speak a little louder and fairly slowly, please, Mr. Rolfsen?

THE COURT: I might remind the witness he is not merely dictating to the reporter. He is giving testmony so that we can all hear it and not merely the reporter.

THE WITNESS: Yes, Your Honor.

BY MR. BEAN:

25 Q Mr. Rolfsen, how long have you been employed by Mr. Broderson? A Two and a half years.

Q Now, what was your formal education? A I received my mechanical engineering degree from New York University.

Q When was that? A July of 1947.

Q Now, in connection with your employment with Mr. Broderson, is that Neil Broderson, who is the plaintiff in this case? A That is correct, sir.

Q In connection with your employment with him, have you become familiar with an invention that he made in internal combustion engines as illustrated in the drawing of his patent application involved in this suit? A That is correct.

Q Have you had occasion during your employment to participate in the construction of an engine built to embody the principles of Mr. Broderson's development? A Mr. Broderson approached me on this problem and explained his theory so I understood it thoroughly, and I proceeded to design an engine that would operate on his principle.

26 Q Now, about when did you start that? A February of 1948.

Q And where was the actual engine built, Mr. Rolfsen? A It was a commercial marine engine made by Palmer Brothers of Cos Cob, Connecticut, their model ZR-1 engine, a one-cylinder marine engine.

Q Could you use it in the form in which you purchased it? A No. Because of the head design, we were unable to use it in its original form. It was a T-head engine and this operation would not allow that.

Q Then, as I understand it, to some extent that basic commercial single cylinder engine was modified by you? A That is correct. We redesigned the head.

Q Where was that work of redesigning the head done? A A good portion of it was done at the factory where I was employed.

Q Then was the engine later tested? A It was tested at the university.

Q What university is that? A The University of Rochester.

Q Where in that university? A In the mechanical engineering laboratory.

Q Now, coming back to the modification that you made
on this engine, modifications with respect to the head of
the engine,in these modifications what did you do in
27 order to, as you have stated, incorporate the principles of the Broderson invention? What did you
do? A We made arrangements for two chambers as Mr. Broderson's invention calls for, with a relative size of 25 percent in the smaller chamber, with 25 percent of total volume, which is in keeping with his instructions.

Q Now, where was the exhaust valve located in the head, if it was in the head? A The exhaust valve was located immediately above the piston.

Q Where was the intake valve located in this engine? A The intake valve was located in the auxiliary chamber.

Q About what is the size and weight of this engine, Mr. Rolfsen? A The engine weighs about 500 pounds.

Q And do you know where it is at the present time? A At the present time it is still on the testing stand at the University of Rochester.

Q Now, in connection with that engine, did you have any igniter or spark plug? A We had the conventional 14 millimeter automobile spark plug.

Q Where was that located? A In the auxiliary chamber.

28 Q What kind of fuel feed system was used in
this modification? A We used an American Bosch standard Diesel injector pump and nozzle.

Q Am I correct, that the fuel was to be put into this engine when operating on the Broderson principle, as you understood it, through what I have called here previously an injector?

MR. MOORE: I think it is leading, Your Honor.

MR. BEAN: I will rephrase it. I do not wish any question raised.

BY MR. BEAN:

Q You have just referred to some kind of American Bosch injection system and nozzle. What was the purpose of that? A In the American Bosch system, we use an injector injection pump which provides pressure on the fuel, and the pressurized fuel is fed through the line in the injection nozzle, and the fuel forced out through little orifices in the injection nozzle.

Q Where is that nozzle on that injection system in that engine located? A It was located in the auxiliary chamber.

Q Were or were not any means provided in connection with that setup for the varying of time of injection?

28-A A On the injection pump, we had an American Bosch primer which enabled us to vary the time throughout the 360 degrees of the cycle.

BY THE COURT:

Q You mean it would be more at some parts of the cycle than others? A I beg your pardon?

Q You mean it would be more in some parts of the cycle than at other parts of the cycle? A The duration of injection could be varied, the amount of fuel put in, and also the time in which it was started.

BY MR. BEAN:

Q Now, would you briefly, Mr. Rolfsen, explain how that engine was operated, if it was operated? Was it operated by you? A It was operated by me.

Q Would you explain just briefly how it was operated, giving the conditions of operation, that is, as to whether it was to simulate part load or full load, and speak up so that His Honor can hear and slow enough, please. A We operated this engine with an injection system and also with a carburetor, making it a conventional induction type engine as in your automobile so we could compare

the two systems.
29 We were able to run tests at all readings, full
load right on down to no load, taking our readings off conventional testing equipment.

Q And am I correct that this engine was coupled up with a dynamometer? A Yes, that is a conventional testing condition device.

Q What did you observe as to the efficiency between the operation with the injection system and the operation of that same engine without the injection system and operated with the use of carburetion. What did you observe? A Operating the engine as an injection engine, using the Broderson method, we had excellent results. It showed an increase in efficiency. The heat of the exhaust gases was considerably lower.

In relation to detonation, we experienced no detonation at all, even though we used Diesel fuel, kerosene, and very low octane gasoline.

However, operating under the same conditions as an induction engine, or carburetor engine, we had a terrific amount of detonation, so much so that we had to stop the engine for fear of destroying it.

The efficiency was several percent lower. Exhaust temperatures were approximately 400 degrees higher.

Q Now, Mr. Rolfsen, did a Mr. Rickard work
30 with you in connection with this testing of this
apparatus? A That is correct.

Q And did Dr. Conta of the University of Rochester participate in the observance of any of these? A That is also correct.

Q Are both of these gentlemen present? A Yes, sir.

MR. BEAN: That is all. You may cross examine.

Cross Examination

BY MR. MOORE:

Q What is the name of the factory in which you are employed, Mr. Rolfsen? A The Rochester Button Company.

Q The Rochester Button Company? A Yes, sir.

Q Would you say that the one-cycle engine that you tested—

MR. BEAN (Interposing): One cylinder.

BY MR. MOORE:

The one-cylinder engine that you tested could be characterized as a compression injection engine? A I don't quite undertand that question.

Q Are you familiar with the term compression injection engine? A Yes, sir, I am.

31 Q Would you say that term applied to the Broderson one-cylinder engine as such and tested at Rochester? A This engine is a spark ignition engine; compression ignition is Diesel.

Q It was an internal combustion engine of the liquid fuel injection type? You would say that much? A Yes.

MR. MOORE: That is all.

MR. BEAN: Does Your Honor have any questions?

THE COURT: No.

(Thereupon the witness was excused and retired from the witness stand.)

MR. BEAN: Mr. Rickard, take the stand.

32 Thereupon,

Corwin Rickard

was called as a witness by the plaintiff, and, being first duly sworn, was examined and testified as follows:

THE DEPUTY CLERK OF THE COURT: Will you state your full name?

THE WITNESS: Corwin Rickard.

Direct Examination

BY MR. BEAN:

Q Mr. Rickard, will you state your place of residence and your occupation and place of occupation? A Yes. I live in Clover Road in Henrietta, New York.

I am an instructor at the University of Rochester in the Division of Engineering.

Q What is your background of formal education, Mr. Rickard? A I received a B. S. in engineering in 1947, June of '47, and June of 1949 I received a Master of Science in engineering from the University of Rochester.

Q As part of your work toward the Master's degree, did you write a thesis or paper on what you understood to be the Broderson engine and the testing of the Broderson engine?

MR. MOORE: I object to that, Your Honor. He has not indicated he has any understanding of the Broderson principle, if there is any such principle.

33 THE COURT: I overrule the objection.

A Yes. In partial fulfillment for the requirements of Master of Science, I completed a thesis on that, the subject of which was the stratification of the charge in the spark ignition engine, and this was intimately associated with Mr. Broderson's method for operating an internal combustion engine.

BY MR. BEAN:

Q Now, as I do not want any question raised, I will ask you, Mr. Rickard, whether you are familiar with the engine of the type shown in this Broderson patent application drawing, Figures 1 and 2, and do you have an understanding of the method of operation for such an engine? A I do.

Q In order that counsel for the defendant will have no question about it, would you briefly, very briefly, state your understanding of the method of operation of the Broderson development? A Yes. I understand the operation of the Broderson method to consist of injecting the fuel into an auxiliary anti chamber during the intake stroke, while the engine is at any place from full load down to no load.

At no load, I understand injection will occur solely

at the very beginning of the compression stroke, and this
method of operation enables you to receive many
34 benefits over the normal operation of an internal
combustion engine.

Q I would like to have you clarify one point there that you have just stated. In any condition of operation from full load down substantially to no load, injection takes place on the intake stroke, that is, the induction stroke.

During such a condition of operation, is it or is it not your understanding that injection carries over into the compression stroke under such conditions? A Yes.

Q What is your understanding of it? A That injection carries over on to the compression stroke.

Q Now, you have heard the word stratification here. It has been the first time it has been used in this courtroom.

I would like to ask you to just explain the word very briefly, what you mean by stratification in connection with this Broderson engine and method and the meaning of it. A Yes, sir. By stratification I mean that we have two homogeneous charges of fuel separated by a definite boundary, and that there is a definite stratification between the two different mixtures, the mixture in the auxiliary combustion chamber and the mixture in the main combustion chamber, and by stratification we mean
that although the charge is homogeneous in each of
35 the separate parts of the cylinder, it is stratified
to the extent that the two parts are separate and
definite and not homogeneous as a total charge.

Q What is your understanding of any reason why stratification, as you have just explained it, is either necessary or desirable in this Broderson device and method? A It is the only way in a spark ignition engine that enables you to utilize very lean overall mixtures, and although the mixture strength in the auxiliary chamber may be slightly rich or at least sufficiently rich to be readily ignitable, the main charge in the main combustion space over the piston can be very lean.

BY THE COURT:

Q How can it be homogeneous in that situation? A Taking up each charge, taking up the two charges as separate, one in the auxiliary chamber and one in the piston, each is a different charge, so we might speak of them as separate charges, and then we would say that the charge in the main combustion space is homogeneous, and the charge in the auxiliary combustion space is homogeneous.

BY MR. BEAN:

Q Following His Honor's question because I think that is a very good point there, you cannot properly say, can you, that the charge, that the complete charge between
all the chambers, as you have about described, is
36 homogeneous? A No.

Q What is that? Is it stratified? A It is stratified.

MR. BEAN: Does that fully answer Your Honor's question?

THE COURT: Yes. I have always understood that stratification referred to horizontal layers and would not be applicable to this situation.

MR. BEAN: I will have some other experts on that.

THE COURT: I simply state that as my present impression of the use of that word.

MR. BEAN: I appreciate very much Your Honor giving that indication to me because I would like definitely to have that cleared up.

I might ask Mr. Rickard here with respect to his understanding of what stratification can be.

BY MR. BEAN:

Q Mr. Rickard, in your understanding of stratification, as you have been referring to the Broderson device and method, is it your understanding that any stratification and difference between masses would be in horizontal layers or could it be in layers other than horizontal, such

as vertical or on a slant? A Well, as the term is used,
it can be other than horizontal, although even in this case,
I might add, that if you were just changing the posi-
37 tion of the auxiliary chamber so that it was pos-
sibly on top, then it would be stratification in hori-
zontal position if you wanted to look at it.

THE COURT: I merely suggested that because my recollection goes back many years when I studied physics, and different strata in physics.

MR. BEAN: I have had that trouble in this case because I was accustomed to thinking of it in horizontal terms.

BY MR. BEAN:

Q Well, now, were you familiar with this test engine described by Mr. Rolfsen? A Yes, I am.

Q You heard him testify as to the general characteristics of construction of that engine? A Yes, I did.

Q Is there anything that you wish to add or change as to your understanding of that engine, as to its physical construction? I am not asking about its operation, now. A No. He described it amply.

Q Now, as to the operation that you observed in tests in that engine, did you make any tests on that engine? A Yes, I did.

Q And over approximately what period of time did you make tests? A I made tests from approximately the middle of September, 1948, until the end of February, 1949.

38 Q Now, what was the purpose of making those
tests? A I was making a comparative study be-
tween Mr. Broderson's method of operating an internal
combustion engine and the normal conventional type of
operation as in the automobile engine.

Q Were tests made at approximate full load, part load, and no loads under comparative conditions? A Yes; tests were made at varied loads under both methods of operation.

Q What did you observe during these tests? A We observed a considerable increase for the Broderson method of operation over that of the conventional operation.

Q Increase of what, speed? A An increase in thermal efficiency, or the degree to which the engine utilized all the energy available in the fuel.

Q Did you observe anything with respect to knock or detonation? A Yes.

Q What did you observe? A While operating under the Broderson method the engine was much more resistant to detonation than operating under the conventional methods.

Q Did you make any observation as to the types
39 of fuel that it was possible to use in the Broderson
method when the engine was set up to operate in that way as compared with the conventional carburetor type engine? A Yes, we ran a variety of fuels in the Broderson method, among which were kerosene and normal heptane.

Q What is heptane? A It is a reference fuel that is used to establish an octane rating for other fuels.

Q Why did you use this heptane? Does it have some particular characteristics that you wanted to observe? A Yes. That reads a zero octane rating. In other words, if the normal fuel which we use in our car would have an octane rating of 60, 65, or possibly 70, this comparatively would have an octane rating of zero.

Q What results did you observe using kerosene, heptane, and these other fuels in the Broderson method as compared with carburetion methods? A We observed that at the same load and under like conditions we could operate under the Broderson method substantially without detonation, while switching over to the conventional method of operation, we had very violent detonation.

Q Without going into it any deeper than necessary because this matter is coming up from time to time, would

you just explain what is meant by octane or octane
40 rating so that I may know what it means? A Yes.
The octane rating of a fuel is its rating in terms of its resistance to detonation in an engine. A fuel that is very prone to detonation in an engine would have a very low octane rating. A fuel that has a high degree of resistance to detonation would have a high octane rating.

MR. BEAN: I think that will be all for direct examination.

Cross Examination

BY MR. MOORE:

Q Mr. Rickard, you stated that you get a rich mixture at the position of the injection nozzle? A I believe I stated that we can obtain a richer, we obtain a richer mixture in the auxiliary combustion space than we would utilize at part load in the main combustion space.

Q Then you get a leaner mixture in the main combustion space? A At a fractional load; yes.

Q Is there any sharp demarcation between those two charges? A No, of course, there is no sharp line of demarcation between them.

MR. MOORE: That is all.

MR. BEAN: That is all unless Your Honor has
41 any questions.

THE COURT: Is that the plaintiff's case?

MR. BEAN: No; I have two more witnesses, Your Honor.

(Thereupon the witness was excused and retired from the witness stand.)

MR. BEAN: Dr. Conta, take the stand.

42 Thereupon,

Lewis Conta

was called as a witness by the plaintiff and, being first duly sworn, was examined and testified as follows:

THE DEPUTY CLERK OF THE COURT: What is your full name, please.

THE WITNESS: Lewis Conta.

Direct Examination

BY MR. BEAN:

Q Dr. Conta, where do you reside? A At 37 Southland Drive, Rochester, New York.

Q And what is your occupation at the present time? A At the present time I am professor of mechanical engineering at the University of Rochester.

Q Would you state your education and line of work, and your profession, starting from your college days, please? A I was graduated from the University of Rochester with the degree of Bachelor of Science in 1934, and I received a Master of Science from the same institution in 1935, and a Doctor of Philosophy degree from Cornell University in 1942.

Q In connection with your Master's degree, Doctor, which you stated you obtained in 1935, did you write a thesis having anything to do with fuels and engine performances? A I did.

43 Q Do you recall the name of that thesis? A I believe the title of the thesis was gasoline octane numbers and engine performances.

Q Now, from 1935 to 1937, what was your position? A I was instructor in engineering at the University of Rochester.

Q In what subjects were you an instructor at that time? A Thermo dynamics, power laboratory, and internal combustion engines.

Q From 1937 to 1946, what were your duties and where? A I was first instructor and then assistant professor at Cornell University.

In the early years, 1937 to 1940, approximately, I taught in the mechanical laboratory, experiments on fuels, heat engines, fuel flow, and related subjects.

Q And how about the period after 1940? A During the war years, the Navy established a large school of Diesel engineering at Cornell University, and I was associated with that school, first in charge of the fuel injection and engine control laboratory and later in charge of instruction in the entire Diesel engine course.

Q That had to do with Diesel engines? A It did.

Q And how about the period from 1946 to 1948,
44 Doctor? A During those years I was employed as
research engineer by the Air Reduction Research Company in their laboratory at Murray Hill, New Jersey.

Q From 1948 to the present time? A In all of 1948, I returned to the University of Rochester as professor of mechanical engineering.

Q Does that have anything to do with internal combustion engines and gas turbines? A I am teaching several of these subjects at the present time?

Q During the past summer have you been engaged in any special work? A During the past summer I was engaged in an extensive survey of combustion engines for the National Research Council.

Q Now, Dr. Conta, I show you a drawing which contains Figures 1 and 2 of the Broderson patent application involved in this litigation, and I will ask you whether you have seen that drawing before? A I have.

Q Do you believe that you are familiar with the construction shown and the method of operation that is described in that patent application? A I am.

Q There has been testimony here, and by two
45 witnesses, with respect to a test engine at the Uni-
versity of Rochester laboratory. Are you familiar with that test engine? A I am.

Q Without going into the detail of construction of that engine, is it your understanding that when set to operate on a fuel injection system, does it or does it not incorporate, in your opinion, the principles of the construction and method of operation of the Broderson development? A

In my opinion, it does incorporate the Broderson method.

Q Were you familiar with or did you observe any of the tests runs where comparisons were made between the operation under Broderson and the operation as a carburetion type of engine? A Yes, I did.

Q Did you observe any advantages or disadvantages that the Broderson might have with respect to a carburetion type? A The advantages that related to detonation were very obvious in observing the operation of the engine.

Q Dr. Conta, with respect to the use of this term stratification, which came up, I had always considered stratification to be in horizontal layers. I believe we asked a question of Mr. Rickard, and I would like to ask it of you: As from a scientific viewpoint in dealing
46 with the term stratification, does it have to be in horizontal layers or could that be in vertical or slant layers?

What is your understanding? Would you speak up just a little louder, please?

A My understanding of the term stratification is that in connection with the art and science of internal combustion engines, it has been extended beyond its perhaps original meaning as applied to geology.

The term is used where a segregation does not involve horizontal layers. That term has been used in that way in connection with internal combustion engines for a good many years now.

MR. BEAN: Your Honor, I have here a series of charts that I would like to have Dr. Conta explain, and for ease of handling, I believe I might offer them nor or offer them for identification and then have the witness discuss them. Whichever you or Mr. Moore wish.

MR. MOORE: Suppose you identify them now.

MR. BEAN: The charts I am offering for identification at this time, Your Honor, are offered as Plaintiff's Exhibits 2 through 7, inclusive.

THE COURT: Very well.

(The documents referred to were marked Plaintiff's Exhibits 2 through 7 for identification, respectively.)

47 BY MR. BEAN:

Q Dr. Conta, are you familiar with these charts, Plaintiff's Exhibits 2 through 7 for identification? A Yes, sir, I am.

Q Now, with respect to the chart, Plaintiff's Exhibit 2, will you describe for the Court what that chart is intended to represent? A The series of drawings pictured across the bottom represent the piston cylinder in the main and auxiliary chambers in several positions of the cycle.

The drawings above represent the position of the piston in various crankcase degrees, at the bottom dead center, which is shown at the center, and we have top dead center at the left; bottom dead center at the center; top dead center at the extreme right, representing two strokes of the piston.

In the first diagram, 20 is to indicate the division between the main and auxiliary chamber and figures indicating the relative volume.

The second diagram indicates the conditions during the suction stroke of the engine. The piston is moving down. Air which is indicated by the green color is being drawn through the intake valve, through the auxiliary chamber, and past the restriction into the main chamber. At this point no fuel has yet been injected.

48 The center drawing, which is immediately below the bottom dead center position in the upper curve indicates conditions at bottom dead center. At that point injection of fuel through the injection nozzle into the auxiliary chamber begins, and the blue indicates the beginning of fuel injection.

Beyond bottom dead center the piston starts to force air ahead of it from the main chamber into the auxiliary chamber, thereby preventing the escape of the injected fuel from the auxiliary into the main chamber.

The fourth picture over to the right indicates the condition partway up with the fuel substantially up in the auxiliary chamber, except for possibly a small amount of diffusion in the main chamber, which is shown by a slight bit of blue over near the throat between the two chambers.

Just before top dead center, shown as 30 degrees in this diagram, the spark plug fires igniting the uniform homogeneous mixture which is present only in the auxiliary chamber, and the main chamber still contains only air.

This represents conditions at very light load, that only enough fuel is injected to turn the engine over against its own resistance or against a very slight load, and that small amount of fuel must be concentrated with a small amount of air so that the mixture will be rich enough to permit ignition.

49 Q Now, in the top portion of this particular chart we have what looks like a roadway or path that makes an angle in the center of it, and has a line that extends down to the letters BDC.

Does that mean bottom dead center? A Yes, that means bottom dead center.

Q Now, to the right of that line and in the bottom of that roadway on what would appear to be a sidewalk, there is a filling in with blue, which is to the right of BDC. What does that represent? A That represents the duration of the injection charge. Fuel begins entering the auxiliary combustion chamber at bottom dead center and continues entering the chamber for approximately 25 degrees as shown here.

Q What chamber does it enter? A The auxiliary chamber only.

Q And then the end of that dark place in what I will call the sidewalk, does that represent the end of the injection? A It does.

Q And then in the section above, indicated just above that, there is a dark blue color. What does that area represent there? A The two center paths labeled at the extreme left as representing the auxiliary chamber and the main chamber.

50 Q Let us reverse that. The auxiliary chamber is the chamber marked near the bottom? A That near the bottom.

Q And the main chamber is the wider one above it? A That is right. The blue spreading area, the area representing the auxiliary chamber indicates that in that auxiliary chamber a uniform homogeneous mixture of fuel and air exists, whereas the green color in the area representing the main chamber indicates that in that chamber only air is present.

Q Dr. Conta, I will hand you a chart—

THE COURT (interposing): Before you take that up, we will take the luncheon recess. I will take this up at 2 o'clock. There will be a General Term meeting of the Court today and we will adjourn until 2 o'clock.

I will take this up at 2 o'clock.

(Thereupon a recess was had from 12:30 o'clock until 2 o'clock p. m.)

After Recess

(The trial was resumed at 2 o'clock p. m., pursuant to the recess.)

Thereupon,

Lewis Conta

resumed the witness stand pursuant to the recess and
51 testified further as follows:

Direct Examination (Resumed)

BY MR. BEAN:

Q Dr. Conta, you had just been discussing a chart, Plaintiff's Exhibit 2 for identification, which was intended purely for the purpose of being illustrative of the Broderson method and operation under a condition of minimum load.

Now, would you please turn to the chart, Plaintiff's Exhibit 3. A I do not have that. Oh, I am sorry, I do.

Q And according to the notation on that chart, following the word "conditions," is the designation "part load."

Now, without duplicating the testimony that you gave with respect to Exhibit 2 in your description of the various portions of the cycle of operation, I wish that you would explain this chart with particular consideration of the period of injection of the fuel and what happens during the time it has been injected and after it has been injected.

Would you do that? A I will.

Q And speak up very loudly so that I can hear you here. A The figure on the left shows, as before, the piston moving down on the suction stroke and plain
52 air entering through the inlet valve and through the auxiliary chamber.

The second diagram, which shows conditions approximately 45 degrees before bottom dead center, indicates the beginning of the fuel injection at that point. Fuel is entering through the injection nozzle into the auxiliary chamber and is being carried by the entering air stream into the main combustion chamber.

The lower narrow path in the upper diagram indicates that fuel injection has begun about 45 degrees before bottom dead center.

Q At that point, Doctor, do I understand that you are now referring to what I believe I previously termed the roadway or path section of this chart? A That is right.

Q And where the lower sidewalk is cut off by color, before you get to the bottom dead center in this particular construction illustration, that is where the injection of fuel is started? A That is right.

Q How long does that injection continue as shown in the illustration? A As shown, it continues throughout the remainder of the down or suction stroke and during the first portion, approximately the first 15 degrees, of the return or compression stroke.

53 Q Now, during that part of the cycle and for the rest of the compression stroke, would you describe what the conditions within the cylinder and in the combustion chambers are as far as fuel mixtures are concerned? A That portion of the fuel which was injected before bottom dead center was carried by the entering air stream into the main combustion chamber and mixed with the air on the beginning of the return or compression stroke. All of that fuel which was injected at that point, that is, beyond the bottom dead center, that fuel remained in the auxiliary chamber because in the compression of air the flow is reversed, the air is flowing from the main chamber into the auxiliary chamber, and in so doing it carries a small part of the previously injected fuel back into the auxiliary chamber.

Q Now, in this particular illustration, at the time illustrated by the illustration at the right-hand portion of Exhibit 3, which I believe would be just at the point of ignition, what is your understanding of what is illustrated as to the richness or leanness of the mixture in the auxiliary chamber and the richness or leanness of the mixture in the main combustion chamber? A The degree of color as indicated illustrates the richness of the mixture. Since
that fuel injected beyond bottom dead center re-
54 mained in the auxiliary chamber, the mixture there
is richer than in the main chamber. It would have
an air fuel ratio in the readily combustible range.

The mixture in the main chamber is very much leaner or lean so that it would not burn of itself but will burn when the hot products of combustion from the auxiliary chamber flow into the main chamber and raise its temperature.

Q Now, as to that mixture in the auxiliary chamber, in your opinion, would or would not that mixture be substantially homogeneous? A It would in my opinion be substantially homogeneous.

Q Have you an opinion with respect to the mixture in the main combustion chamber? A I believe that, too, would be substantially homogeneous.

Q I call your attention to the chart, Plaintiff's Exhibit 4, which following the word "conditions" carries the notation "full load."

Now as to that particular chart, without repeating what you have testified with respect to the other charts, but in any condition which this changed, will you describe the changed condition, Doctor? A In order to bear increased load on the engine, additional fuel is required. In order to provide that additional fuel, the injection period must
be lengthened. The beginning of injection is in the
55 line approximately 75 degrees before bottom dead
center as compared with 45 in Exhibit 3.

Therefore, more fuel is injected during the suction stroke, which fuel mixes intimately with the air in the main chamber, being carried there as before by the entering air stream, a small amount of injection, and continues beyond bottom dead center, as before, and the fuel so injected remains in the auxiliary chamber resulting in a mixture richer there, slightly richer than in the main chamber.

Q Now, in this illustration at the time of ignition, in your opinion, would the mixture in the auxiliary chamber, would it or not be a substantially homogeneous mixture? A Yes, it would be substantially homogeneous.

Q And with respect to the mixture in the main combustion chamber? A That also would be substantially homogeneous.

Q Now, Doctor, in these three instances that you have given, as illustrated in these charts, am I correct, that in each case in the auxiliary combustion chamber there has been at the time of ignition an ignitable homogeneous or substantially homogeneous mixture? That is correct.

Q Now, with respect to the mixture in the main combustion chamber, has the mixture in each of these three cases been of the same richness or leanness, or has it varied? A It has varied from case to case.

56 Q Now, in varying or in connection with these variances of the mixture in the main combustion chamber, what factor or factors in this Broderson development would you consider were necessary to bring about this condition where you have in one chamber an ignitable mixture, substantially the same in these three cases, and in the other main combustion chamber we have a mixture which has a varying concentration of richness. That is, as between the three instances, what conditions make that possible in the Broderson? A Well, first, the fact that the injection into the auxiliary chamber occurs partly in the suction and partly in compression stroke, so that the portion of fuel injected during the intake stroke will mix thoroughly with the entering air, and that part which is injected in the compression stroke will be confined to the auxiliary chamber, and in addition, in order to get the substantially homogeneous mixture, sufficient time must be allowed for mixing and diffusion to take place. Therefore, that fuel must be in early, well before ignition.

Q Has the size of these two combustion chambers anything to do with this? A They do in this respect: In order for the engine to run at all, an ignitable mixture must be present at the spark plug. If the mixture becomes excessively lean, ignition will not occur.

57 In order to have the small amount of fuel necessary to run the engine at no load, a mixture with only sufficient air to form a combustible mixture, the auxiliary chamber must be reasonably small. If that chamber is large, the small amount of fuel necessary will result in a lean mixture which will not ignite.

Q Is there any type of restriction or constriction or anything of that nature between the two chambers necessary or desirable to assist in achieving the result that has been illustrated? A Yes, there is.

Q What is the purpose or function of the restriction, such as shown between those chambers? A Restrictions for the purpose of forming two chambers in each of which a uniform homogeneous mixture can be obtained.

THE COURT: Read the answer, please.

(The last answer was read by the reporter.)

BY MR. BEAN:

Q Well, now, let us go into this from your theoretical viewpoint. What is the desirability, if any, of having a homogeneous mixtures, Doctor? A A homogeneous mixture will fire more completely than a non-homogeneous mixture, with resulting higher efficiency. Furthermore,
complete utilization of the air in an engine is only
58 possible if the mixture is homogeneous.

To put it another way: If the mixture is not homogeneous, then there will be molecules of fuel and molecules of oxygen which will not meet and will not combine, and there will be un-combined oxygen and fuel.

Q Now, Doctor, counsel for the defendant has advised that the defendant will rely upon three prior art patents in connection with this proceeding as being the principal or most applicable of the patents of the prior art.

So I would like to ask you to discuss these prior art patents for the benefit of the Court, and the first one mentioned by counsel is the Mock patent, 2,142,280.

MR. BEAN: Does Your Honor have that before you?

THE COURT: Yes.

BY MR. BEAN:

Q Dr. Conta, have you studied this Mock patent? A I have.

Q Do you consider yourself to be familiar with the structure that is shown and described and the method that is described in this patent? A I do.

Q Now, would you start with Figure 1 of this patent, that is the figure in the upper left-hand corner of the
drawings, and will you describe that structure for the
59 benefit of the Court? A Figure 1 shows the cylin-
der and piston arrangement, having two valves, an intake and exhaust valve, and an auxiliary chamber off to

the upper left containing a fuel injection nozzle and two spark plugs.

The operation, the mode of operation, four strokes of the cycle, are exactly those found in normal engine operation. In this design, on the intake stroke the air is drawn into the main chamber, not through the auxiliary chamber, drawn directly into the main chamber.

Q Is that post of the valve designated with the numeral 10? A That is right. No, I believe 10 is the exhaust valve.

Yes, this picture 1 shows the engine at the end of the exhaust or near the end of the exhaust period, and the gases shown by small curved lines are thrown out by exhaust valve 10. After that exhaust stroke is over, the piston will start down and the intake valve 11 will open, and air will enter through intake valve 11 into the main chamber, not through the auxiliary chamber.

Q Now, Dr. Conta, this is a point that I believe is of considerable importance in the consideration of this matter. You have just referred to an auxiliary chamber in Mock, and that auxiliary chamber is the numeral 15 with a lead line extending to it? A Yes.

Q And you have referred to a main chamber, and that appears after the numeral 23, somewhat centrally located above the piston? A Yes.

Q That particular view that you have discussed would give the impression that there is a substantial size main chamber 23. I will call your attention to the figure just below it, Figure 4, and will ask you to describe the position of the piston designated with the numeral 9 in that picture. A That figure shows the piston at or near top dead center, and it is obvious from this picture that the chamber shown as 23 in Figure 1 has disappeared, that there is substantially no volume above the piston, other than the chamber, than that found in chamber 15.

Q With respect to Figure 1, Doctor, observing the angle of inclination of the broken off portion of the connecting rod, which is at the bottom of the figure, and just to the right of the arrow pointing up, is that piston there at the top dead center position or is it in some other position? A It is well below top dead center position.

Q Am I correct in my understanding, when that particular piston reaches top dead center position it will be substantially at the height as shown in Figure 4? A It will be at least at that height.

61 Q Now, there is a view at the lower left-hand corner of this drawing, which is designated Figure No. 6, and without regard to what the modification is at this time, I will ask you to describe the height of the piston with respect to the top of that structure or cylinder head. What do you understand from that drawing as to that position? A I would say that position is at or near top dead center.

Q In your opinion, is there any substantial chamber between the top of the piston and the top of that horizontal portion of the cylinder head that has no number? A No, there is not. In my opinion, all the volume existing in the cylinder when the piston is at top dead center is encompassed in one chamber.

Q Now, coming back to this structure then shown in Figure 1, the top left-hand corner of this drawing, in the combustion chamber 15 are there igniters or spark plugs shown, and if so, how many? A There are two shown.

Q They bear the numbers 20 and 21? A That is right.

Q Is that structure shown between the two spark plugs and designated with the numeral 18, is that an injector or a portion of an injector? A That is my understanding.

62 Q Now, to further clarify this point that you brought out in your earlier testimony, as to whether or not there is an auxiliary combustion chamber and a main combustion chamber in Mock, I will call your attention in the patent specification, to page 2—make that page 3, column 1, the line starting at 13 with "the."

The patent there states: The provision of the combustion chamber relatively remote from the engine cylinder and the manner in which the fuel is injected therein results in a more complete vaporization of the fuel than is possible in engines of the compression ignition or Diesel type.

Now, from your understanding of that terminology, that portion that I have read and other parts of this specification, how many combustion chambers are there in this mock patent?

A My understanding is that there is only one.

Q Do you find any basis for that undertanding in the language of the claims? I am not asking you to interpret the claims but just the language of the two claims of this patent.

Do they refer to one or more than one combustion chamber?

A Each claim refers to a combustion chamber of heart-shaped form.

Q Now, Doctor, would you describe your understanding of the operation of the device of this Mock patent?

A My understanding is that fuel is injected
63 through injection nozzle 18 into the chamber early
in the cycle and is held there by the piston raising
and forcing air into the chamber. The result will be a mixture which varied in richness from the injector out towards the entrance to the cylinder 16.

Q Now, in that chamber designated with the numeral 15, in your opinion, when the piston is approaching the top dead center postion and which is prior to ignition, is the mixture in that chamber 15, according to your understanding of what the patentee intends here, is that a homogeneous mixture? A No, it is not. The patentee definitely represents it as a non-homogeneous mixture and strives to obtain such a non-homogeneous mixture.

Q At that particular point do you have any understanding why he shows two spark plugs instead of, we will say, one spark plug for an igniter in this particular construction? A Since the entire air quantity at top dead center is contained in chamber 15, or substantially the entire quantity is in chamber 15, an ignitable mixture will only exist in some portion of the chamber and it will not be a homogeneous ignitable mixture throughout the chamber but will be ignitable only in some portion of the chamber, and by having two spark plugs the patentee hopes that the ignitable mixture will be in the vicinity of a spark plug.

Q Well, now, consider that this piston in this
64 Mock patent is at top dead center position as is
illustrated in Figure 4. A Yes.

Q At that time in Mock and disregarding whether or not the mixture in the chamber 15 is homogeneous or nonhomogeneous, is it possible to have a substantial mixture above the piston between the piston and the lower part of the cylinder wall, which would have different characteristics or different mixtures than that contained in the chamber 15, or would the constituents of the mixture be somewhat similar? A The volume in the space to which you refer is so small that it would be likely to be a mere continuation of what exists in chamber 15.

Q Now, let us assume it will be possible for Mock to vary the time of the injection of the fuel at will. Would it be possible in Mock to bring about a condition wherein there is an ignitable mixture in chamber 15 that would be a mixture of sufficient richness to be ignited, and a mixture outside of chamber 15, above the piston, that would be of a different degree of richness, so that, in your opinion, you could obtain the results that you have described in connection with the Broderson method? A No. In my opinion, that would not be possible.

Q Dr. Conta, would you advise the Court of any way
that you know of in which you could apply the
65 Broderson patent as taught in the Broderson appli-
cation to the structure shown in this Mock patent?

A No, I do not. Mock definitely maintained all of the injected fuel in chamber 15.

In Broderson, the chamber into which the fuel is injected is swept by the entire air, or the fuel is carried out of the chamber. There is not, in my opinion, any point of similarity in that respect.

Q Dr. Conta, under your direction I understand there has been prepared this chart to be illustrative of the Mock patent. This is Plaintiff's Exhibit No. 5 for identification.

MR. BEAN: Your Honor, there is some question in my mind and my assistant's as to whether all your copies are colored, and if you come across any that is not colored—

THE COURT (interposing): This number 3 is not colored.

MR. BEAN: I see. I will see that that is done this evening, Your Honor.

THE COURT: Number 4 is colored.

MR. BEAN: Thank you. Number 5, is that colored, Your Honor?

THE COURT: Yes, 5 is colored.

MR. BEAN: And 6?

THE COURT: And 6 and 7.

MR. BEAN: Fine. Thank you.

66 I would like to have this number 3 colored this evening.

THE COURT: I will leave this with you so you can color it between now and tomorrow morning.

MR. BEAN: I would like to do that, Your Honor.

BY MR. BEAN:

Q Now, with respect to this chart, Plaintiff's Exhibit 5 for identification—

THE COURT (interposing): What exhibit number?

MR. BEAN: Number 5, Your Honor.

BY MR. BEAN:

Q Would you explain what is intended to be shown by this particular exhibit? A This exhibit shows the operation of the engine according to Mock—of Mock's engine according to Mock. In this engine, at least in one method of operation of this engine, some fuel is injected during the exhaust stroke of the previous cycle, and the first diagram shows that condition, is intended to show that, and the base arrow shows the condition shown in the first diagram to the left, and represents a condition somewhat before the end of the exhaust stroke in the section labeled "preceding exhaust stroke."

At that time the combustion chamber, the heart-shaped combustion chamber is filled with exhaust products from the previous cycle, and fuel is injected into the exhaust products in order to utilize the hot temperature of
67 these products, to vaporize and prepare the fuel for combustion.

The suction stroke proceeds normally. The compression stroke again proceeds normally, air being forced into the combustion chamber.

The combustion has not been swept at any time by any other gases, so the fuel has remained within that chamber at all times.

Near the top of the compression stroke, shortly before top dead center, ignition occurs burning the fuel which exists in that chamber, driving the piston down on the power stroke.

The last diagram represents the end of the exhaust stroke with the heart-shaped combustion chamber again filled with exhaust gases prepared for the next injection.

Q Now, there has been some discussion with respect to the term or word "stratification."

To consider stratification in the sense of your understanding of the Broderson patent, is it possible to obtain that type of stratification with the structure and method of the Mock patent, in your opinion? A In my opinion, it is not. Broderson's concept is stratification in the two homogeneous mixtures isolated from one another.

In Mock, there is no possible provision for two homogeneous mixtures but rather for one non-homogeneous in a single chamber.

68 Q Now, Dr. Conta, are you familiar with the fact that Broderson has varying times in which he can inject this fuel into this chamber? A Yes.

Q And I hand you a chart for identification, Plaintiff's Exhibit 6 for identification, and I will ask you whether the variation shown in the chart, in your opinion, finds a basis or is based on the variation of the Broderson patent? A No, I do not.

Q I mean, of the Mock—pardon me, Mock. A This is a modification of the Mock patent.

Q Would you briefly describe to the Court what that variation is that is referred to in Mock and which is illustrated on this chart? A This differs from the previous method of operation by the Mock in that the fuel injection takes place at different portions of the cycle. In this case his injection fuel is taking place during the intake stroke of the engine as shown by the diagram to the left. Air is entering the cylinder and fuel being injected into the combustion chamber. That fuel injection ceases approximately 30 degrees before bottom dead center, as shown by the blue line in the upper sidewalk.

Q Now, as to that, Dr. Conta, in this particular
69 roadway or path that is illustrated, we do not have
any bottom sidewalk, do we? A That is right.

Q There is just a top sidewalk, and what is that top sidewalk illustrating or intended to be illustrative of? A It is intended to illustrate the injection of fuel into the combustion chamber.

Q And then according to that part that is colored off in that upper sidewalk, there was injection from approximately 90 degrees down to 30 degrees in the intake stroke; is that right? A That is right.

Q And then what happened? A There is no further injection until near the end of the compression stroke, with the piston nearly at top dead center and just before ignition. At that point the additional fuel is injected into the combustion chamber to insure further that an ignitable mixture will be found near one of the spark plugs.

Q Now, with that particular type of fuel injection in that Mock patent structure, is it possible to get a homogeneous mixture in that combustion chamber? A It is not homogeneous. It is not possible to get a homogeneous mixture, and it would not be desired by Mock to get a homogeneous mixture.

70 Q With this type of varied injection of fuel in this alternative method of the Mock patent, in your opinion, Doctor, would it be possible through the use of such a variation of injection to utilize the Broderson method on this for in this Mock construction? A In my opinion, it would not be possible.

Q Doctor, the next patent that counsel for defendant advises he places principal reliance upon is the British patent 373,647.

Your Honor, that is Exhibit "C".

THE COURT: Yes, I have it.

BY MR. BEAN:

Q Now, have you studied and are you familiar with that British patent, Dr. Conta? A Yes, I am.

Q Looking at the Figure 1 of the drawing, would you explain your understanding of the structure and the method of operation of the structure of this British patent? A This patent shows the normal piston and cylinder mechanism with valves suitably arranged for injecting air and discharge exhaust products. It shows an injection nozzle marked "H" injecting into a chamber marked "F," which is separated by a restriction over the space above the piston, a small space marked G2.

This engine is a straight Diesel engine. It does
71 not have a spark plug for ignition and operates on
a different principle from the Otto cycle we have
been discussing.

Q Now, would you for our information, Doctor, explain at this point what a Diesel engine and its operation is so as to give us guidance? A In a Diesel engine, the suction stroke always inducts pure air, never a combustible mixture, and on the up stroke of the piston, on the compression stroke, the pressure is carried to a much higher value than in the case of the Otto cycle engine to, say, 500 pounds per square inch instead of 100 pounds per square inch.

Q Why is that? A At that high pressure the air becomes heated to such an extent that it will give us ignition of the fuel sprayed into it without the use of any auxiliary ignition system.

Q Now, in Diesel type of operation, what are the characteristics of the fuel sprayed into the cylinder? A A Diesel fuel, a low volatility fuel is injected into the cylinder at the time when combustion should begin, and since the air is already hot enough to spread the combustion, the time of beginning combustion is controlled only by the time of the injection of fuel into the engine.

Q And is that injection instantaneous or does it
72 carry on for a period of time? A That injection
carries on for a period of time. During this time
the fuel is injected, the fuel ideally continues to burn as it is injected.

Q In what direction is the piston moving during a major portion of the fuel injection in the Diesel type? A Most of the fuel is injected past top dead center, while the piston is moving downward on the expansion or power stroke.

Q What are the advantages of the Diesel type operation as compared with the convention Otto cycle type of operation? A One of the major advantages of the Diesel cycle is that at part load operation small quantities of fuel can be injected, put into the fuel charge of air. Under this method of operation, such mixtures would burn due to the hot air temperature, and therefore operation becomes possible with very lean overall mixtures. This results in a very high efficiency.

Q At part load? A At part load.

Q Now, Dr. Conta, with respect to this British patent, if you will come back to that, please, this chamber designated with the letter "F" does that stay hot or get cold, or what is the normal condition of that as to temperature
during operation? A Normally that chamber would
73 be hot and would operate at an elevated temperature.

Q Does that have any purpose in this Diesel type of device? A It helps prepare the fuel for more rapid combustion.

Q Now, in this particular British patent structure and method of operation, do you at any place in any chamber get a homogeneous mixture? A No. In my opinion, you do not. There is insufficient time available for a homogeneous mixture to form.

Q Is it characteristic, not only of this patent but of all Diesel operations generally, that it is a non-homogeneous mixture? A That is characteristics of Diesel engines.

Q Now, at the time when the piston in this British patent is at top dead center, do you find in this patent two chambers, two combustion chambers, one the auxiliary combustion chamber of not more than equal size as compared to a main combustion chamber? A No, I do not. The main combustion chamber, it could be called that G2, obviously is very small compared with chamber F.

Q Now, in this construction as shown in the patent with the method of operation, in your opinion, is it possible
to obtain a type of stratification that you considered
74 in connection with the Broderson developments? A
No, in my opinion, that is not possible.

MR. BEAN: Your Honor, I will want to go to another patent.

THE COURT: I think we will adjourn. I will take this up at 10 o'clock tomorrow morning.

(Thereupon, at 3 o'clock p. m., an adjournment was taken until 10 o'clock a. m., Thursday, November 3, 1949.)

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75 UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA
NEIL O. BRODERSON, Plaintiff,
v.
LAWRENCE C. KINGSLAND,
Commissioner of Patents, Defendant.
Civil Action No. 4789-47.

Washington, D. C.,
Thursday, November 3, 1949.

Pursuant to adjournment theretofore taken the trial of the above-entitled case was resumed at 10:00 o'clock a. m., on Thursday, November 3, 1949, in the United States District Court for the District of Columbia, in the Court House, at Washington, D. C.

BEFORE:

HONORABLE JENNINGS BAILEY, District Judge of the United States District Court for the District of Columbia.

APPEARANCES:

HAROLD T. STOWELL, ESQUIRE, and EDWARD T. BEAN, ESQUIRE, on behalf of the Plaintiff; and

CLARENCE W. MOORE, ESQUIRE, on behalf of the Defendant.

76 PROCEEDINGS

THE DEPUTY CLERK OF THE COURT: Broderson v. Kingsland.

THE COURT: Proceed with this case.

MR. BEAN: Dr. Conta, resume the stand.

Thereupon,

Lewis Conta

resumed the witness stand pursuant to the adjournment and testified further as follows:

Direct Examination (Resumed)

BY MR. BEAN:

Q Dr. Conta, when we adjourned yesterday we had practically completed a discussion on your part of the British patent 373,647, which is Exhibit No. "C" of the defendant's exhibits. I just have two more questions to ask you with respect to that matter.

First, Dr. Conta, in your opinion, does this British patent teach or suggest the method of the Broderson patent application? A No, in my opinion, it does not.

Q Now, assuming that it would be possible in some way to join or combine this British patent with the Mock patent, 2,142,280, which you have already discussed, in your opinion, would the combination of those two patents either teach or suggest the Broderson method? A In my opinion, no combination of these two patents
77 would suggest the Broderson teachings.

Q Now, Dr. Conta, the third patent that counsel for the defendant referred to in his statement, that the defendant would place reliance upon as being one of the principal prior art patents is the Werner patent 1,616,157, and that is in the patents as Exhibit "K", Your Honor.

Now, Dr. Conta, have you studied this particular patent? A Yes, I have.

Q Would you explain to us, please, the structure shown on the first page of the drawings indicated by Figure 1, just briefly, what that structure is and what the method of operation of that structure is as taught by Werner? A The structure involves the usual piston, cylinder, valve mechanism, a combustion chamber R, and an ignition chamber for retort K.

THE COURT: Let me find that, please.

BY MR. BEAN:

Q Does that combustion chamber R lie directly above the head of the piston? A It does.

Q And it is marked with the capital letter R in a kind of concealed position, isn't it? A That is right.

MR. BEAN: Has Your Honor found that?

THE COURT: Yes, I have found it.

78 BY MR. BEAN:

Q And then above that and to the right there is a small light or uncolored opening that has in the center of it the capital letter K. Is that the retort that you mentioned? A That is the retort.

Q Would you continue your explanation somewhat slower, if you please? A The main teaching of the Werner patent is concerned with a method of controlling combustion in such a way that part of the fuel is burned at constant volume as in the Otto cycle, and the major portion of the fuel is burned as it is injected at constant pressure, in accordance with the Diesel principle. That is, the first portion of fuel burned while the piston is substantially at the top of its stroke, and the major portion of the fuel burns as the piston moves down and at such rate as to maintain substantially constant pressure above the piston.

Q Now, Doctor, this structure would tend to be a little confusing, and I will ask you to follow me with respect to it. The main combustion chamber R has an extension going upwardly, and coming down into the top of that chamber in what appears to be a pipe, and at the top of the pipe is the capital letter N.

Is that the injection device for the main combustion? A It is. 79

Q Now, going over then to the right, just a bit into what the patent calls the retort K, am I correct that right above the letter K is an igniter or spark plug that has a lead line going from the top of it to the capital letter S? A That is correct.

Q And then also entering into that chamber K, from the lower right-hand side is another pipe line, and if we follow that pipe line down to a point near its bend we will see the letter L prime.

Is that a secondary or another injector? A That is right. L prime is the fuel line feeding it in prime, and the lead line indicates the injection valve itself.

Q Now, in the right-hand portion of that retort K there seems to be a valve and that is designated to the right with the numeral 18.

Am I correct, Dr. Conta, that that valve under certain types of usage by Mr. Werner will open a passageway which will draw fuel and air in through a carburetor which is designated with the capital letter M? A That is right.

Q Now, starting at the beginning of a stroke, we will say the compression stroke, when the piston is coming up, what is the operation of this Werner device, if that
80 is a reasonable place to start? A It is.

The fuel which is placed in retort K, in a cage as it is, the main function is ignition of the main fuel injected into combustion chamber R. That fuel may be introduced into K by injection nozzle N prime as the piston approaches the top of its compression stroke, and that fuel is intended to be ignited. That mixture resulting from that fuel is intended to be ignited by a spark plug S, and in the hot products of combustion, the flame will pass through passageway 20 and 21 to the combustion chamber, that is, ignition can be of fuel not substantially pure, a power carrying quantity of fuel.

At the same time as that injection begins or possibly before or possibly a little later, the main power fuel is injected through the main injection nozzle N, and as it spreads past down 20, it is ignited by the hot products leaving the retort, and that main fuel burns as it is injected, supplying the main power charge to the engine and maintains pressures substantially constant as the piston moves down on its expansion stroke.

Q Now, how is air in that method of operation that you have just described, how is air brought into the combustion chamber R? A It is brought in through
81 an intake valve which is marked 9.

THE COURT: Just a minute. Let me find 9.

THE WITNESS: It is to the left of chamber 21, actually in this drawing marked 9 prime, and 9 lies behind it.

THE COURT: Yes, I see it.

THE WITNESS: And the main is brought in it, directly in the main chamber R.

BY MR. BEAN:

Q Now, is there any other method of operating described by Werner whereby he can utilize this carburetor M? A There is.

Q And would you describe that method whereby the carburetor M is used? A The carburetor is used for an alternate method of supplying the ignition charge to retort K. That ignition charge must be a combustible mixture prepared in the carburetor M of gasoline and air which is admitted to retort K through valve 17, or 18. 17 points to the valve stem.

That charge is merely an ignition charge and again combustion of that charge is used to ignite the main power carrying charge injected through the main nozzle N directly into the combustion chamber.

Q Dr. Conta, so that I can get down to some possibly more simple understanding of analogy as to the function of retort K, is that in any way similar to what we
82 commonly know of as a blow torch playing out a
hot flame into the path of something that it is going to set on fire? A It does have that action, and the blow torch action of the hot gases serve to ignite the fuel being injected through nozzle N.

Q I wish you would turn to the next page of the drawing, Dr. Conta, to Figure 8 in the upper right-hand corner of this page, and there is a somewhat different structure shown there; is that correct? A That is correct.

Q Now, would you describe the structure which is shown in Figure 8 in so far as it differs from the structure that you have previously described? A The structure shown in Figure 8 is in substantial degree the same, as far as performance is concerned, as that shown in Figure 1.

There is still a retort K fed by valve 17 and provided with the ignition device S.

There is still restriction 20, and while the main flow of pure fuel injected by nozzle N passes the mouth of 20, it is exposed to the blow torch action of the igniting charge of retort K.

Q Where does the main body of air come into this particular structure that you are now describing that enters into the combustion chamber that is immedi-
83 ately over the piston? A That enters, as before, through a conventional inlet valve indicated by the figure 9 leading directly into the main chamber.

Q Now, Doctor, let me ask in this Werner construction and the performance you have described, whether or not it would be possible using that construction and the Werner method of operating to obtain in what we will call the main combustion chamber, to obtain a homogeneous mixture of fuel and air? A No, it would not. To obtain such mixture requires time for preparation, time for mixing, and in the Werner device the fuel is burned as it is injected.

Q Now, let me ask you, Doctor, whether or not there would exist a homogeneous mixture in this retort portion K of the Werner device? A In the method of operation involving the auxiliary injector N prime the mixture would not be homogeneous.

In the case where the carburetor is used, a carburetor will always supply a homogeneous mixture or substantially a homogeneous mixture. That is the nature of a carburetor.

Q Now, Doctor, with respect to Werner, in your opinion, does Werner either teach or suggest the Broderson method of operation? A In my opinion, the dis-
84 closures of Werner do not teach or suggest the method of Broderson.

Q Doctor, among the charts which were identified yesterday is a chart, Exhibit No. 7 of the Oscar Werner patent number 1,616,157.

THE COURT: Number 7?

MR. BEAN: Number 7, Your Honor. That should be the last one of that set.

THE COURT: Yes, I have it.

BY MR. BEAN:

Q Would you tell us and describe what is shown on that chart and what it is intended to illustrate? A This is intended to illustrate the operation of the Werner patent in which the carburetor is not used and in which the injection valve supplies the ignition fuel.

The first diagram to the left below indicates the suction stroke with air entering through the main valve and air also being supplied through the auxiliary valve.

The second diagram indicates bottom dead center with the piston prepared to move up on the compression stroke, and both valves closed.

Now, the diagram above, the roadway type, is indicating nothing but air throughout the intake stroke and the major portion of the compression stroke. Near the end of the compression stroke both injectors begin injecting
fuel simultaneously, the injection of fuel into the
85 retort indicated by the lower sidewalk.

Then the diagram above is of short duration, intended to supply only the ignition charge of fuel, and the injection into the main chamber indicated by the upper sidewalk begins at the same time, to extend through the entire period, and does extend into the power stroke and supplies the main power charge of fuel.

Shortly beyond the injection, ignition is indicated in the auxiliary or retort chamber. This ignition causes a blow torch action into the main chamber and ignites the main fuel. That part of the main fuel which was injected before ignition burns immediately and at substantially constant volume. That portion of the main fuel indicated in the upper sidewalk, which is injected beyond ignition time, burns substantially as it is injected, and according to the teachings of Werner, maintains pressure above the piston substantially constant during the early part of the power stroke.

Q Dr. Conta, going back now to the tests that were made in the laboratory of the university at Rochester of an engine which was modified to incorporate the Broderson structure and method of operation, did you have anything to do with those tests? A I did.

Q What was it? A I directed the work of Mr. Rickard and Mr. Rolfsen.

86 Q Now, in connection with the operation during those tests, I believe that you have already advised us that the Broderson operation as distinguished from the carburetor operation during the test, the Broderson operation was superior as far as detonation or knock characteristics were concerned?

Have you so testified? A I have.

Q Were there any other differences that you observed during that time, that is, comparatively between the Broderson method of operation and the carburetor method of operation? A Yes, I did observe that at any condition less than full load the economy of the Broderson method of operation was substantially better than that for the carburetor operation, and such increase in economy would result in considerable fuel savings under the load conditions which are most commonly experienced in most automotive type engines.

Q Did you make any observation with respect to whether or not it was possible to utilize in the Broderson method, to use a possibly lower quality of fuel as compared with that that could be used in a similar engine under the carburetor method? A The fact that detonation is substantially controlled by the Broderson
87 method would show that poorer grade of fuel could
be used, and we observed that in the operation of the engine.

MR. BEAN: That completes the direct examination, Your Honor.

Cross Examination

BY MR. MOORE:

Q Dr. Conta, you have decribed the Broderson engine with reference to Figures 1 and 2 of his application drawings, didn't you? A Yes.

THE COURT: Which is that?

MR. MOORE: This, Your Honor, is sheet 1 of the application drawings.

THE WITNESS: I don't believe I used that.

MR. BEAN: That, Your Honor, is exhibit number N, the drawing of the patent application of Mr. Broderson.

BY MR. MOORE:

Q You were asked about this particular sheet during your examination, weren't you? A I am not sure; perhaps.

MR. BEAN: Yes, Dr. Conta was asked.

THE WITNESS: Yes, I was. I have seen so many sheets, I didn't know which.

BY MR. MOORE:

88 Q The portion at the right-hand of Figures 1 and 2 shows what that applicant characterizes as an auxiliary chamber; isn't that true? A That is right.

Q Will you define the boundaries of that auxiliary chamber? A Well, it is bounded by the circular line bounding the right-hand circular section.

Q It is a generally circular chamber? A It is shown so in this diagram.

Q And has generally a cylindrical wall? A It is so shown here.

BY THE COURT:

Q Just a minute, please. Is that circle drawn around the center of figure 8, number 8, is that circle merely a drawing or is it intended to show some piston separation? A No, there is an opening connecting the two chambers.

Q I do not understand why this circle extended around that. A That represents the lower wall which can be seen forming the complete circle in which the piston moves.

BY MR. MOORE:

Q It would indicate, Dr. Conta, that the cylinder extends below the auxiliary chamber A That is right.

89 Q Now, you would say that there is a mouth between the auxiliary chamber on the right and the main chamber to the left? A That is right.

Q To what circular extent would you say that mouth is? A Just—

Q (Interposing) In degrees? A In degrees, as shown in the diagram, I would say it covers perhaps 20 degrees.

THE COURT: Will you gentlemen step to the bench a minute? I will tell you the difficuty I have.

(Thereupon counsel approached the bench and the following occurred:)

THE COURT: As I understand it, this goes at right angles to this?

MR. MOORE: That is right.

THE COURT: What I am trying to find out is what that line means, if that is a physical demarcation, or what is it?

MR. BEAN: That line, Your Honor, is right here. In other words, this portion would be right here. It is the cylinder wall or piston here, and this is really curved if it was completed.

THE COURT: It is an extension if the piston was produced?

90 THE BEAN: That would be that line there.

THE COURT: Is there any physical separation between this chamber and this chamber?

MR. BEAN: No, it is not, Your Honor.

THE COURT: That is what I could not understand, whether there was or not.

MR. MOORE: If you put a plain edge there, you get the projection.

THE COURT: I see what you mean. I wanted to know whether there was any physical separation between this chamber and this chamber.

MR. BEAN: There is none.

While we are both here and because this is brought out in connection with this particular patent, the only thing that is between this chamber and this chamber is the restriction caused by this curving edge coming out there, so as to leave this open, and that has a mouth, which is this area going right through there. It is just the restriction caused by those.

You are correct on that, Your Honor.

THE COURT: Very well. That is what I was not sure about.

(Thereupon counsel resumed their places in the courtroom and the following occurred:)

BY MR. MOORE:

91 Q When you suggest that mouth extends about 20 degrees, do you mean 20 degrees from either side of the central line? A Well, perhaps 30 degrees altogether.

Q At least 30? A Yes.

Q Now, return to the description of that auxiliary chamber. Describe it briefly in relation to the boundary walls. A I do not quite understand.

Q You mentioned the fact in response to my question that one boundary of that auxiliary chamber was a generally cylindrical wall with a mouth opening? A That is correct.

Q Now, what other boundaries does that chamber have? A Well, it has a floor formed as an extension of the main engine structure, in the top formed by the cylinder head.

Q The floor is that portion by that reference numeral 3? A That is correct.

Q And the ceiling is the portion that contains the valve 7? A That is right.

Q Do you find any obstruction upstanding from
92 the floor of that auxiliary chamber? A No.

Q Do you find any obstruction extending downwardly from the ceiling? A None, other than the intake valve.

Q Do you find any obstruction at the mouth? A The obstruction formed by the two lips which form the mouth of the chamber.

Q I am talking about a projection extending downwardly from the ceiling at the mouth? A There is none shown in that diagram.

Q Do you have a copy of the Mock patent before you, Dr. Conta? A Yes, I do.

THE COURT: Of what patent?

MR. MOORE: The Mock patent, Item G of the defendant's sole exhibit.

BY MR. MOORE:

Q You have referred in your testimony on direct examination, as I remember it, to reference numeral 23 as denoting a chamber. Will you check reference 23 in the specifications to see if it refers to a chamber? A Are you asking me about this?

Q Yes. A Numeral 23 refers to what is more
93 commonly known as cylinder volume. It is the volume swept by the piston.

BY THE COURT:

Q That is what? A Cylinder volume, the volume swept by the piston as opposed to the combustion chamber, which is that volume remaining when the piston is at top dead center.

BY MR. MOORE:

Q Will you refer to the specification, and I call your attention to the second paragraph in the second column on page 2? Locate the reference numeral there and tell me what 23 relates to. A Where was that?

Q Page 2, second column, second paragraph, and particularly line 25. A Page 2, column 2, line 25?

Q That is right. A As indicated by short curved lines 23.

Q What do the short curved lines 23 indicate? A These short curved lines indicate hot burned gases.

Q And you find that again in Figure 2, don't you? A That is right.

Q In both, the heart-shaped chamber and in the section above the piston? A That is right.

94 Q And the same curved lines in figure 3? A That is right.

Q Now, what do the plus marks 25 in Figure 3 indicate? A The plus marks indicate air.

Q Air referred to by what reference numeral? A 25, I believe.

Line 35, indicated by the crosses 25. Together with air, indicated by the crosses 25.

Q The specification calls for crosses rather than plus marks? A Yes.

Q Now, there is an indication on this patent of exhaust gases and an indication by crosses of air.

Now, what other indications are there? On the left there are dots? A There are dots, which I believe represent the fuel.

Q Dots 24; is that right? A That is right. That appears in line 23. The relative positions of the fuel vapor 24. 24 represents the fuel vapor.

Q So the patent itself lays out quite specifically the location, distribution of fuel, air and exhaust gases; is that true? A As shown by the pictures; yes.

Q Your answer is "Yes"? A As shown by the picture; yes.

95 Q Now, Figure 2, to which you previously referred, shows what you have designated as a heart-shaped chamber? A That is right.

Q It also shows a space above the piston 9 and below a cylinder wall that contains valves 10 and 11; isn't that true? A It shows part of the cylinder volume which is to be swept by the piston.

THE COURT: Which figure is that?

MR. MOORE: Figure 2.

BY MR. MOORE:

Q I am asking you if there is any space shown between the cylinder head and the top of the piston 9? A There is a space shown there because the piston was not yet reached the top of the stroke.

Q I asked you whether the space shown there—

THE COURT (interposing): Can you answer that?

MR. MOORE: It is tied up with the specification, Your Honor, too.

BY THE COURT:

Q As I understand your position, it is that the position of the piston rod indicates whether the piston was at the top of the stroke. A That is right.

96 Q And Figure 6, that would show the piston was at the top of the stroke? A That is right.

BY MR. MOORE:

Q Let us turn, Dr. Conta, to the British patent, item C of defendant's exhibit, and I ask you if it is not true the specification of that British patent says that the chamber F, which it calls an ante chamber— A (Interposing) Yes.

Q Is substantially equal to the clearance space above the piston? A Yes, that statement is made.

MR. MOORE: I have no further questions.

MR. BEAN: That is all. Thank you, Dr. Conta.

(Thereupon the witness was excused and retired from the witness stand.)

97 MR. BEAN: Mr. Brush, take the stand.

Thereupon,

Lanson P. Brush

was called as a witness by the plaintiff and, being first duly sworn, was examined and testified as follows:

THE DEPUTY CLERK OF THE COURT: What is your full name, sir?

THE WITNESS: Lanson P. Brush.

Direct Examination

BY MR. BEAN:

Q Mr. Brush, would you state your place of residence and your occupation, sir? A My residence is in Detroit, Michigan, and my occupation is that of consulting engineer.

Q Over the past years have you had any experience with the automotive business and with automobile engines? A I have; practically continuously for the last 47 or 48 years.

Q Starting from the time of your contact with the automobile business, would you state the nature of your experience and your occupations at various times? A My first contact with the automobile industry, Your Honor, was through my being delegated to supervise the method of manufacture and a method, a mode of testing for delivery of engines and transmissions being made
98 under contract by the firm which employed me, engines and transmissions for use in automobiles manufactured by the then Olds Motor Works of Detroit.

The Olds Motor Works had been previous to that been makers of stationary Otto cycle engines for power purposes. The firm employing me, the Leland, Faulconer Manufacturing Company, was given a contract by the Olds Company to manufacture engines and transmissions in considerable quantity for that day, a couple of thousand sets, and to deliver these engines and transmissions ready for installation in the automobiles purchased by the Olds Motor Works.

That work involved the design and supervision of design of special tools, and supervision for use in the production of the engines, and certain modifications in the original design of the ordinary engine so they would lend themselves better to efficiency production and be a better product.

Subsequent to the completion of that contract for the Olds Company, the same company employing me undertook the manufacture of a somewhat similar power plant for a group of Detroit investors who wanted also to get into the automobile industry, and which group later organized an automobile company called the Cadillac Automobile Company.

I designed and supervised the production methods and the production of the engines and transmissions for the first models of the Cadillac Company. That engine like
99 the Olds engine was an Otto cycle gasoline burning internal combustion engine.

I also designed for the Cadillac Company a type of 4-cylinder engine to be used in a shaft drive car, which type of engine, built in various sizes, was the Cadillac type of engine used until the V-8 engine was adopted by the Cadillac Company, supplanting the vertical 4-cylinder engine.

After some three or four years work with the Leland, Faulconer and Cadillac Company, which included the chief engineership of the Cadillac Company, as well as special work with the Leland, Faulconer Company, I resigned those two positions and took some time out for research work, and I built in that work for my own use and study a small run-about, which incorporated a number of features that have since become standard in automobile production.

That was a single cylinder engine car, and that engine again was an Otto cycle gasoline burning internal combustion engine.

I also organized the company which originally was known as the Oakland Motor Car Company and was so named until after its purchase by the General Motors Company, and later the name was changed to the Pontiac Division of General Motors, as it now exists.

When the Oakland Company was taken over, I resigned

my position of vice president and chief engineer
100 with the Oakland Company and made my headquarters at Flint at the Buick Motor Company as consultant to all of the then existing divisions of the General Motors Company.

In those positions I designed two different engines for the Oakland Company, each of them again being an Otto cycle internal combustion engine burning liquid fuel.

In my position as consultant to the Buick Motor Company, I supervised the design of the first overhead valve engine used by the Buick Motor Company in which the old practice of having individual valve cages for each valve was discarded and the present type construction of overhead valve motors was introduced through the Buick production.

In those engines exhaust and intake valves are mounted directly in the removable cylinder head, and that is the practice on today's Chevrolet and Buick engines, both.

In 1913, I resigned from my position with the General Motors Company, and I have since that time maintained my own office in the City of Detroit, doing general consultant work of various kinds, but principally in connection with the automotive industry and much of that consultant work being in connection with automobile engines.

Q Mr. Brush, during the past five or ten years, would you state the names of a few of your clients in the automotive industry for whom you have acted as consultant?

A Oh, yes. The Ford Motor Company, Chrysler
101 Motor Company, General Motors Company, Packard Motor Company, and the American LaFrance Fire Engine Company for their factory at Elmira, New York.

I designed for them and supervised in a consulting way the introduction into commercial production of 12-cylinder engines, which they have used since 1930, I believe, and I think they are still using.

Q Now, Mr. Brush, I will show you the drawing, which includes Figures 1, 2, and 3, that is the drawing of the application for patent of Mr. Broderson that is involved in this particular litigation, and I will ask you whether you are familiar with that drawing and with the application for the patent and whether you consider that you understand it? A I am familiar with the drawing and the Broderson application for patent here today.

Q Do you have an understanding as to the method which the Broderson application for patent purports to teach? A Yes, I have.

Q Without going over the details of the structure as shown in Figures 1 and 2 of the Broderson application, except to a sufficient extent for your explanation, will you give the Court your explanation of your understanding of the Broderson method? A Yes. First, Your Honor, the Broderson method is a modification of what we
102 know as the Otto cycle, one of the two conventional 4-cycle internal combustion engine cycles as distinguished from the other commonly known 4-cycle type internal combustion engine known as the Diesel cycle.

This Broderson application is a disclosure of a proposed modification of the Otto cycle internal combustion engine, which modification consists briefly in providing for Otto cycle combustion at the time of ignition two masses of compressed air, each in all loads except minimum load, each of the masses having some fuel, the same degree of or amount of fuel in proportion to the air, substantially homogeneously diffused throughout each of the two masses.

The one mass in the auxiliary combustion chamber always having a degree of fuel diffusion through it so that it is ignitable by spark ignition, and the other mass of air in the main combustion chamber may have a combustible mixture for full load or nearly full load operation.

At less than full load operation, the mixture in the main combustion chamber is less than optimum burning mixture in varying amounts but at minimum load, no fuel at all.

These two masses of variously fueled air under compression are joined by a transition zone, the maintenance of which transition zone requires a degree of constriction at the two ends or the boundaries of the transition zone, where the quality of mixture of one gradually is varied
as it travels in the direction to the mixture in the
103 other mass of air.

Q Mr. Brush, would you hold up that sheet of the drawing and indicate to His Honor the point of the transition zone between the chambers you are referring to, and the restriction? A In the drawing, Figure 1, Your Honor, which is a horizontal section, through Figure 2 and the lines 1-1, looking downward, and that shows the main combustion chamber indicated by the reference line and the numeral 6, and the auxiliary combustion chamber is indicated by the reference line leading into the chamber and the numeral 5.

The transition zone is bounded generally by the adjacent curved boundary lines where they approach nearer together than the diameter of either of the combustion chambers.

That transition zone and the need for the restriction to determine that zone, Your Honor, is due to the Broderson mode of operation in which the air is drawn into both chambers during the intake stroke, through the opening of the intake valve, which is shown in the drawing, Figure 2, in the auxiliary combustion chamber, the arrow pointing downward indicates direction of flow of air into the valve pocket, and when the valve is opened through the flap into the auxiliary combustion chamber, so that as the piston moves downward drawing air in through the opened inlet
valve, there is a continuous flow of air through the
104 intake stroke through the air in the auxiliary
chamber, through the restriction and into the main chamber and down into the part of the cylinder vacated by the downwardly moving piston.

Do I make that clear, Your Honor?

Now, during that intake stroke, if more than a minimum power output is to be required from the modified Otto cycle engine, which we might perhaps call the Broderson cycle, during the intake stroke or a portion of it, there will be injected into the auxiliary combustion chamber through the injection device indicated by the numeral 10 in Figure 1, there will be injected into that auxiliary chamber a spray of rather finely divided fuel particles, and due to the flow of air through the combustion chamber that fuel so injected into the auxiliary chamber during the suction stroke of the engine cycle, that is, while the piston is moving downward, air from this upper position, below the main combustion chamber, that air flowing through the auxiliary chamber will sweep the injected fuel through the restriction outlining the transition zone and into the main body of air in the cylinder and in the main combustion chamber.

When the piston is at down stroke, when the movement of the piston is reversed and the inlet valve and exhaust valve are both closed, on what we call the compression stroke, as the piston moves upward and the beginning of
that upward movement, the injection of fuel into
105 the auxiliary chamber is continued beyond the
reversal of the downward movement of the piston
in the downward movement on the compression stroke, so that fuel then will be injected into the auxiliary combustion space while the piston is moving downward with both valves closed.

Now, Your Honor will clearly see, looking at Figure 1 and 2, that as the piston moves upward compressing the entire body of air in both combustion chambers, it is necessary in order to compress air in the auxiliary chamber, that there be a movement of an appropriate percentage of air through the restriction into the auxiliary combustion chamber.

Now, if there were no restriction at all, or to make it still more obvious, if the auxiliary combustion mass flared upwardly in this connection with the main combustion chamber, so that as compression takes place the movement of air due to the turbulence in the cylinder induced by the current of air as drawn in would produce eddies and make the transition zone very much deeper, and would, in fact, practically without some restriction destroy the ability of it otherwise to carry out the Broderson process, destroy the ability of the Broderson process to prearrange for and have at the end of the compression stroke two homogeneous masses of mixed air and fuel, which homogeneous masses of mixed air and fuel are, in fact, connected with and connected to each other by a transition zone of some considerable extent or depth.

106 BY THE COURT:

Q Is that constriction between the two parts there in the nature of what some patent drawings call a baffle? A Call a baffle?

Q A baffle. A Not exactly.

A baffle is ordinarily used, Your Honor, in air flow to change its direction, to strike a baffle and flow along.

In this restriction, the purpose of it, mechanically speaking, is to be sure that during the compression stroke substantially all air movement is in to the auxiliary combustion chamber and that that movement into the combustion chamber will be sufficiently limited so that there will be no inflow at one side and outflow at the other as would be the case if there were none.

Q To a certain extent, it is to limit the flow with reference to the other? A In the restriction as shown, as Your Honor will readily see by looking at the depth of the restriction, as shown in the Figure 1 section, the restriction is substantially greater in area than the capacity, the flow capacity than the opening area of the inlet valve itself, so that the velocity of movement through the restriction will be always lower than the rate of flow through the valve.

So in that way it is apparent, I think, that while
107 the restriction may make some trifling resistance to free movement, it is of negligible amount. The

restriction only needs to be enough to prevent eddies being formed in the transition zone, which would destroy the homogeneous character of the mixture to be ignited in the auxiliary chamber.

Q It is to limit to a certain extent the rapidity of flow from one zone to the other; is that it? A No. As a matter of fact, the piston coming up at a certain rate, the piston making its compression stroke, the piston having a much greater area than the restriction, the piston pushing the air up would make and produce a flow through the restriction of somewhat higher speed, considerably higher speed than would be the flow into the auxiliary chamber if there were no restriction.

THE COURT: Very well.

THE WITNESS: But with engine motion, we would see that the restriction should be as little as possible that would maintain the integrity of the transition zone. That is its sole purpose.

BY MR. BEAN:

Q Now, Mr. Brush, in the—

BY THE COURT:

Q (Interposing) Well, just a minute. You used the word restriction. What does it restrict, the amount of flow, or the rapidity of flow, or the amount of compression?
108 You speak of it restricting something. What does it restrict, rapidity of flow, or amount of flow, or the degree of compression? A No. I used the term restricted in the sense that the cross sectional area of the transition zone position is less than the curved sectional area of either of the combustion chambers.

THE COURT: All right. Very well.

THE WITNESS: Not a restriction of mechanical action, merely a restriction or diminution or reduction. Reduction would have been a much better word for me to use, Your Honor.

BY MR. BEAN:

Q Mr. Brush, along that same line, in order that we may have it clear, what is the purpose of that part, I will call it restriction, and how does it actually operate, in your opinion? What is the purpose of it? Why do we have it there? A Well, to maintain the ability of the system to predetermine and have in existence at the point of ignition two masses of mixed air and fuel in a homogeneous condition, substantially well diffused, and still be able to have the variation desired and needed, and the necessary difference in the quality of mixture in the two connected masses of compressed air.

Q Without a restriction, Mr. Brush, would it
109 be possible in an engine of that type to get two homogeneous mixtures of air and gas in positions adjacent to each other? A Not with any certainty of the approximate volume of each. The volume would be unstable and indeterminate if it were not for some degree of, and I will use the word reduction, some degree of reduction in the cross sectional area of the struction where the transition zone is desired in operation.

Q Now, along this same line, Mr. Brush, is it possible in your understanding of the Broderson method to obtain combustion where you have a relatively rich mixture in the auxiliary chamber, which is where the spark plug and intake valve and air intake valve is located, and a very lean mixture in the main combustion space at the time of ignition? A Certainly it is possible to have a mixture of any desired quality within the ignition range in the auxiliary chamber, and have any degree of leaner mixture desired in the main chamber down to substantially pure air.

Q And how in Broderson do you obtain that difference in mixtures between the two chambers when desired? A Well, for example, Your Honor, let us assume that we want just fuel in the auxiliary chamber, no fuel in the main chamber, pure air.

Then when the piston moves downward on its suction

stroke, no fuel will be injected into the auxiliary
110 chamber because during the downward suction stroke
of the piston the inlet valve is open and there is a continuous flow of air through the auxiliary chamber sweeping the chamber and flowing through the auxiliary chamber into the main combustion chamber and the part of the cylinder being evacuated by the downwardly moving piston, so no fuel can be injected into the auxiliary chamber during the intake stroke without substantially all of that fuel getting into the main chamber and the part of the cylinder evacuated by the piston on its downward stroke.

Therefore, under the conditions I have outlined where a fuel mixture is required and desired only in the auxiliary chamber, the injection of fuel will not begin until the intake stroke has been completed, until the inlet valve is closed and until the flow out of the auxiliary chamber into the main chamber has ceased, and then at that time, at and after the point of reversal of the piston movement and the closing of the inlet valve, when the movement of air is about to start from the main chamber into the auxiliary chamber, then and only then can the injector be put into action and spray fuel into the auxiliary combustion chamber, and only so much fuel as will be required to give the desired grade of mixture in the auxiliary combustion chamber.

When that amount of fuel has been delivered, injection must stop, fuel input, injection must cease, and the piston
continues its movement upward and air continues
111 to be forced into the auxiliary combustion chamber,
until a predetermined compression of this Otto cycle engine has been reached at upper dead center, during all of which compression stroke there has been movement of air from the main combustion chamber into the auxiliary chamber and due to the reduction in area, the movement has occupied all of the cross sectional area of the restriction, and no fuel has been eddied out into the main com-

bustion chamber and all or the greater part of the compression stroke has been timed to provide for diffusion of the fuel throughout the mass of air being compressed into the auxiliary chamber.

Q Now, Mr. Brush, let me ask you this: What particular value has such structure and method? A Well, without at the moment going into explanation, Your Honor, I will simply say this: that if we are to get adequate return in usable power by the burning of fuel in an internal combustion engine, to get the maximum results in an Otto cycle engine, for example, fuel must be burned so as to heat a mass of air which air has been compressed up to the 100 percent of the chosen compression for that engine. That is a condition that the Broderson mode of operation establishes by its modification of the Otto cycle engine.

In the engines we are now using in automobiles, other than Diesel or semi-Diesel, in the Otto cycle engine, which is practically the universal engine for passenger or 112 pleasure cars, privately owned cars, and when you release the pressure of your foot on your accelerator, what you do actually, what you do is close a throttle into a throttle of the manifold between the engine and the carburetor and reduce both air and fuel amounts substantially alike.

So that let us say at a point where half as much fuel and half as much air is taken into the engine, the compression existing at the time of ignition and at top dead center will be only 50 percent of the compression in that engine running at the same speed with throttle wide open.

Now, burning 50 percent of fuel and 50 percent of air with 50 percent of compression will by no means give 50 percent of push down ward on the piston during the working stroke, Your Honor. The ability of the fuel, of the heat generated by the fuel in the mixture to produce mechanical force, to deliver power to the piston, is greatly affected by the amount of compression of the air being heated.

BY THE COURT:

Q Let me go back a minute. As I understand it, the piston on its down stroke draws in air, and as it reaches bottom and starts up, for a short time fuel is let into the auxiliary chamber when the piston moves upward. A On the compression stroke.

Q Then, as I understand it, compression is completed,
and you speak of the fact that the piston drives air
113 into the auxiliary chamber and that that baffle,
whatever you call it, prevents the mixture from getting to the main combustion chamber.

Now, then, can there be two combustion chambers if there is no mixture in the main combustion chamber? A perhaps I didn't make it clear, Your Honor.

What happens is that because air is flowing and freely into the auxiliary chamber throughout the area between the two chambers, the fuel stays in the auxiliary chamber.

Now, in this Broderson modification of the Otto cycle, a 100 percent charge of air has been taken in there. I have presupposed a smaller power output, such that we only want a mixture in the auxiliary chamber, but it is of great advantage to have a heat that is generated when the mixture is burned, and that mixture only burns well through a limited range, about 15 units of weight of air to 1 unit of weight of fuel. That is a rough approximation of what we call the optimum burning mixture.

Now, if in the operation of the Broderson cycle, which I have described, if this fuel in the auxiliary chamber was eddied out and mixed with a total volume of air, the mixture would not ignite, it just would not burn, so for purposes of getting combustion promptly, Otto cycle combustion, that is combustion of widely varying compressions
and constant volume, and if we want to get quick
114 complete combustion we would need in the auxiliary
chamber about a 15 to 1 mixture, and in place of the 50 pounds compression, the full 100 pounds compression in an engine designed for 100 pounds of full compression.

Q If combustion takes place only in the auxiliary chamber, why do you refer to the other as a combustion chamber? A It doesn't take place only in the auxiliary chamber because when under the conditions I outlined, after ignition, then the flame propogation goes through the homogeneous mixture, and there is a rush of flame burning fuel and combined air out into the main combustion chamber. We no longer care about the segregation there.

The transition zone has served the purpose of giving us the right mixture for ignition. After ignition is established, heat is being generated, pressure and temperature are rising, and we want this restricted opening—it has to be large enough so that burning fuel and air can rush out into the mass of pure air in the main combustion chamber and heat all the air substantially alike.

THE COURT: Very well.

I will take a 10-minute recess.

(Thereupon a short recess was had.)

BY MR. BEAN:

Q Mr. Brush, I would like to clear up one matter
here and that is: If we have in what I call the
115 main combustion chamber pure air, no fuel in it,
how do we bring about any burning or combustion in that chamber? Why do we call it a main combustion chamber? A Well, for two reasons. One because at higher loads you will have fuel in that chamber, and two, the second reason, because we are only concerned in keeping fuel out of that chamber up to the point and time of ignition. After ignition takes place, the flame propagation is established, and then inevitably the flame and such of the fuel as is yet unburned and much of the air that was in the auxiliary chamber expands into the other chamber.

I might summarize, I think, Your Honor, that the problem of Broderson to increase the economy of the Otto cycle engine at lower power outputs hangs on this proposition: It must establish a means and the method by which the Otto cycle burning can be accomplished with a reduced amount of fuel and unreduced amount of air, and that means that at the point of ignition there must always be the something nearer what I call the optimum burning mixture because the Otto cycle requires very rapid combustion at widely varying pressures with little variation of volume during the early part of the combustion. In that sense it is different from the Diesel cycle, which I won't go into unless Your Honor wishes it.

So that I have outlined to Your Honor in my answer
to the question just before the condition that would
116 obtain with the Broderson cycle where the amount
of fuel was reduced until there would be no need
of any fuel at all in the main combustion chamber, up to
the time of ignition.

Do I make that clear?

THE COURT: I see what you mean, yes. I understand it.

BY MR. BEAN:

Q Without going again into any of the reasoning behind it, Mr. Brush, is that of any practical value in connection with fuel savings or fuel consumption? A Indeed it is. As I previously pointed out, the unmodified Otto cycle, when it is burning half the amount of fuel required to give full power is giving much less than half of the full power.

With the Broderson cycle operating, the burning of half the amount of fuel will give something more than half the full power output if that half amount of fuel is burned in accordance with the requirement of the Otto cycle in an unreduced amount of air.

Q Now, would you turn to the prior art patents, to Mock, that is exhibit G? That is number 2,142,280. A I have it.

Q Have you studied that patent of Mock and do you consider yourself to be familiar with it, Mr. Brush? A I have and I do.

THE COURT: What number is that?

117 MR. BEAN: That is number G, Your Honor.

THE COURT: Very well.

BY MR. BEAN:

Q Now, Mr. Brush, without repeating the testimony that was given by Dr. Conta in detail, Mr. Brush, and I believe that His Honor by his questions shows that he understands it pretty clearly—

THE COURT (interposing): You flatter me, Mr. Bean.

MR. BEAN: Well, Your Honor asked a question in view of Figure 2, with respect to that space that was shown there between the top of the piston and the bottom of the valves, that there was a space, and Your Honor pointed out, as I recall it, that the rod shows straight up and down, or the piston did not indicate at that time being at the top.

BY MR. BEAN:

Q But I would like to ask you, Mr. Brush, when the piston of Mock is at the top dead center, how much of an area or volume of space is there between the top of that piston and the underneath part or ceiling of the cylinder head? How much space or volume is there in comparison with the space or volume in this combustion chamber that is designated with the numeral 15? A Well, I would not pretend to give the precise quantity of fuel, but the drawing shows clearly what we practice in commercial engines today, where you have a compres- 118 sion of a head, just clear of the compression of the cylinder head, just clear of the piston at top dead center, we call that simply the required the mechanical clearance for safe operation of the engine, and more than that, its vertical dimension, its thickness, so to speak, Your Honor, is so limited that it can in no sense be called a combustion chamber. It lacks both volume and it lacks form.

Q Because you have just been over the Broderson method, the result that Broderson obtains, I would like to ask you whether that same method and same result is, in your opinion, obtained in this Mock structure? A It is not.

Q Is there anything comparable to it obtained by the Mock structure or method? A It is my considered opinion that there is not.

Q Now, in Mock is it possible, Mr. Brush, to vary the richness or leanness of a fuel charge mixture in the main combustion chamber, to vary that with respect to another combustion chamber that is somewhat adjacent, so that we have two different areas of homogeneous mixtures varying in their richness? A There is no such possibility shown in Mock, and perhaps the most obvious reason to a skilled mechanic is that there is but one combustion chamber provided.

119 Q In the one combustion chamber that is provided, Mr. Brush, what is your understanding from the teaching of Mock as to whether or not there is a homogeneous mixture in that one combustion chamber? A He does not—Mock does not even pretend to have a homogeneous mixture at the time of ignition.

Referring to the text of the Mock patent on page 2, line 68, column 1, to line 8, column 2, it says: "In operation of that form of the invention illustrated in Figures 1 to 4, and referring to Figure 1, it will be apparent that fuel may be injected into chamber 15 through the nozzle 18 during the late exhaust or early intake strokes of the piston, the requiring being that the fuel must not enter too greatly into the piston displacement chamber. In certain instances, it may also be desirable to inject a portion of the fuel charge insufficient of itself to propogate combustion, early in the cycle, as for example, during the intake stroke, and then inject the remainder of the fuel just prior to ignition."

Now, when fuel is injected into a single combustion chamber just prior to ignition so as to provide a combustible charge at the points of the spark plugs, and the text shows a mixture too weak to support combustion.

that is a pointing out of a variable fuel contained in a different part of the same chamber.

Q Now, Mr. Brush, so that we will have no misunder-
standing with respect to a main and auxiliary com-
120 bustion chamber, as to whether or not it is present
in Mock, the Board of Appeals of the Patent Office
in its decision in this matter stated as follows, quote: "The patent to Mock discloses a 4-cycle internal combustion engine including a main combustion chamber, which is formed between the top of the piston 9 at its uppermost position, the under side of the piston head and the restriction 16, and an auxiliary combustion chamber 15 communicating with the main combustion chamber through a restricted passage 16."

Now, Mr. Brush, I appreciate that there is an obvious mistake made in that statement where it stated that the main combustion chamber is formed with the under side of the piston head. That would about put it down in the crankcase below, but if we consider that to be the upper side of the piston head, in your opinion, as a practical man and after I have read you that portion of the Board's decision, as a practical expert, disinterested, in your opinion, does Mock show in the light of the teaching of Broderson a main combustion chamber and an auxiliary combustion chamber as the Board of Appeals has stated in its decision? A Mock does not.

Q Now, further with respect to Mock, in the decision of the Board of Appeals on page 4 of their decision, they recite in Mock the step of injecting a portion of the fuel
charge during the compression stroke, that is, just
121 prior to ignition, and they state:

"This fuel charge is injected into the auxiliary combustion chamber 15 through the nozzle 18. The step of igniting the mixture is performed through operation of the ignition device 20 and 21. It is clear therefore that all of the method steps recited in Claim 1 are disclosed in the Mock application and that the only feature whereby this claim may be said to differentiate from the Mock patent is in the structural limitation to the effect that the volume of the auxiliary chamber does not exceed the volume of the main combustion chamber at top center position of the piston."

Now, Mr. Brush, I would like to read now to you, in view of that portion of the Board of Appeals' decision, portions of Claim 1 of this Broderson application and ask whether or not you find them to be present in Mock, and the first portion is that: "The engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage."

I believe you have previously stated that there is in the light of Broderson no main combustion chamber of substantial size; is that correct? A In Mock?

Q In Mock. A No, there is no main and auxiliary
combustion chambers existing at the time when the
122 piston is at upper dead center.

Q Now, the claim continues in this way: "Supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine."

Now, where in Mock, Mr. Brush, can it be pointed out "Supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine"?

Can you point that out?

A I cannot.

Q Now, the next portion of the claim continues: "Injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber."

Can you find that in Mock, Mr. Brush?

A I cannot.

Q And the claim continues: "And to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber."

Do you find in Mock any ignitable fuel mixture in
123 the auxiliary chamber, or this chamber 15, always
ignitable irrespective of variation of composition of the fuel-air mixture obtained in the main combustion chamber? A If Mock's single combustion chamber is called an auxiliary chamber, there is no main chamber. If it is recognized for what it is, the main chamber, there is no auxiliary chamber.

BY THE COURT:

Q As I understand your contention, in Mock there is only one combustion chamber? A In the patent to Mock, Your Honor: When the piston is at upper dead center.

BY MR. BEAN:

Q On page 4 of its decision the Board stated as follows: "It is clear therefore that all of the method steps recited in Claim 1 are disclosed in the Mock application and that the only feature whereby this claim may be said to differentiate from the Mock patent is in the structural limitation to the effect that the volume of the auxiliary chamber does not exceed the volume of the main combustion chamber at top center position of the piston."

Now, is that statement, in your opinion, correct, Mr. Brush? A That statement, in my opinion, is profoundly in error.

124 Q Now, the next statement is that: "We do
not find it inventive, however, to apply the process clearly disclosed in the Mock patent to an engine in which the auxiliary combustion chamber is not larger in volume than the main combustion chamber in view of the British patent."

Now, let us proceed to the British patent, Mr. Brush.

That British patent is Exhibit C, Your Honor, and that is number 373,647.

Mr. Brush, have you studied and are you familiar with this British patent number 373,647? A I have studied the British patent and I am familiar with its disclosures and descriptions.

Q Now, is there in the British patent, according to your understanding, any chamber wherein there is a homogeneous mixture of fuel and air, substantially homogeneous mixture just prior to a period of ignition? A There is not.

Q So that we won't confuse His Honor, Mr. Brush, could you just briefly describe what this British patent is about?

This is one of those Diesel type of devices, Your Honor, that we haven't paid too much attention to.

A This British patent is a device aimed solely at the accomplishment of certain advantages of performance in the other commonly used 4-cycle engine, the Diesel cycle, the cycle in which substantially instantaneous
125 burning is not required and is not tolerated. It is
the type of cycle in which the fuel is burned at a constant pressure and over a substantial period of time, time enough for a substantial amount of piston movement, where the compressions of the air are four or five hundred pounds per square inch, and the fuel ignites when it is sprayed into that highly compressed air, and as the patent, this British patent says, on page 2, column 2, lines 76, 77 and 78:

"The fuel injection is timed to occur near the completion of the compression stroke of the engine."

That is very nearly at top dead center when the compression is of the air at four or five hundred pounds a square inch, so the spray of fuel, plus certain heat factors here, so that the spray of fuel will promptly ignite, will burn not instantaneous as the whole charge, or substantially so, but burn at the rate at which it is put in, so that the pressure rise will be little, if any, above compression pressure at the end of the compression stroke.

The Diesel cycle is intended to never have a pressure materially higher than the compression of the air alone provides, but to have the compression pressure constant at the burning of the fuel in that compressed air as the piston moves away from top dead center position.

Q Now, Mr. Brush, the Patent Office coupled up this British patent with the Mock patent, as I just
126 quoted from the decision of the Board of Appeals.

Now, is the shape of that combustion chamber, and we called one heart shape, or heart shaped, and I am talking about the Mock patent. The shape of that construction of the combustion chamber in the Mock patent is that considered by Mock to be of any importance, the shape of his combustion chamber? A That is, as far as the description given of his device by Mock, is one of his major objectives. What he is seeking to do is to prevent detonation, which is objectively any noise, which is objectively any strain, which is objectively any waste power, to prevent detonation by having a twin flame front.

We speak of internal combustion engine combustion as being a flame which starts, where spark plugs are used, it starts at an electric arc front between two metallic points and ignition takes place, and that flame in a homogeneous mixture will propogate substantially at equal rates in all directions. We speak of the outer surface of that spherical flame extension as the flame front.

Now, of course, it is not spherical because your spark plug, has adjacent metal. As Mock correctly has drawn, the flame front is partially spherical. He has drawn it in his Figure 4, the enlarged section. There are several different points of propogation, and he makes a decla-
127 ration that if the flame front is not allowed to trap
any unburned fuel between the flame front and the wall of the combustion chamber, he can avoid, you can avoid detonation. That may or may not be true.

In Figure 4 he has enlarged it to draw a picture in which he describes that progressive flame front.

There are two spark plugs traveling through this heart-shaped combustion chamber down toward the strangle passage into the cylinder displacement of the engine, and he says when it gets down there, at the passage 16, the flame front will meet unfueled air, pure air, lying on top of the piston, and that will prevent detonation occurring at that point where the flame front would trap mixture between the flame front and portions of the wall surface.

Q In your opinion, Mr. Brush, as a practical man, would it be possible without interfering with the teachings of Mock to incorporate into Mock the structure of this British patent that we have just discussed? A Well, you certainly could not incorporate the structure of the British patent that I assume the Patent Office referred to, namely, the part shown in Figure 3 and also part of that from G2 up to the line above.

Q That is on sheet 2 of the drawing? A Figure 3. In Figure 2, or that shown in Figure 1 where that same part is shown installed in the engine.

128 Chamber F inside this member G is, I suppose, what the Patent Office referred to. That, of course, could not in Mock have its function as in the British patent, and I see no way in which it could have any useful function at all in Mock. Certainly, however, combined with Mock, that kind of chamber could not be by any stretch of the imagination the Broderson auxiliary chamber because, as I have already pointed out, Your Honor, the Broderson auxiliary chamber is air swept, all of the air, and in the figures we have referred to, all of the air going into the engine goes through the auxiliary chamber of each cylinder.

Q Now, Mr. Brush, if we assume that it were possible to combine this teaching structure of the British patent together with Mock, in your opinion, would that teach or suggest the Broderson construction or method that we have described? A It would not.

THE COURT: How much longer do you think you would take?

MR. BEAN: Your Honor, I have been watching the clock. I do not know how long you wish to sit but I can be through in another 15 or 20 minutes.

THE COURT: How about you?

MR. MOORE: There will be very little cross examination on the present content of the direct.

THE COURT: I did not understand you.

129 MR. MOORE: There will be very little cross examination on the present direct examination.

THE COURT: I will take it up at 1:30 or complete it now.

MR. BEAN: I can complete it by 1 o'clock, Your Honor, if you wish. Whatever you wish, sir.

THE COURT: I think I will let it go over until 1:30. Be back then.

(Thereupon, at 12:30 o'clock p.m., a recess was taken until 1:30 o'clock p.m.)

After Recess

(The trial was resumed at 1:30 o'clock p.m., pursuant to the recess.)

Thereupon,

Lanson P. Brush,

resumed the witness stand pursuant to the recess and testified further as follows:

Direct Examination (resumed)

BY MR. BEAN:

Q Mr. Brush, would you turn to the Werner patent, number 1,616,157.

That is Exhibit K of the defendant's exhibits, Your Honor.

Now, Mr. Brush, have you studied and do you consider yourself to be familiar with this patent? A I
130 have studied the patent and I am familiar with it.

Q I don't want you to go into detail as to the construction or method of operation as was done by Dr. Conta, but I will ask you with respect to this particular patent, the patent structure, in what portion of the device is the main charge of the fuel that is to be burned or combusted, in what portion of the device is that injected? A That main portion of the fuel is injected into the space above the top of the piston and the lower face of the cylinder head space marked R in Figure 1.

Q Are separate means used for the introduction of fuel, or a fuel mixture into the part marked A, which the patentee calls a retort? A Yes. Two alternative separate means are shown and described.

Q Now, in this combustion chamber designated with the numeral R in this Werner patent, while there is fuel in that particular chamber and at the time of the start of combustion or ignition is the condition in that chamber a homogeneous mixture of whatever fuel may be present together with air? A No, it is not.

Q In that respect, is that condition of not being homogeneous, is that characteristic of the Diesel type of operation? A It is.

131 BY THE COURT:

Q Why is that not homogeneous? Why do you think it is not homogeneous? A Your Honor, the fuel is, the delivery of fuel through N into that chamber R begins very briefly before ignition starts, and this is an engine in which that fuel burned in the chamber R has to be burned at constant pressure over a period of time, a condition the antithesis of the Otto cycle characteristic, where burning as such is as nearly as instantaneous as possible, and in the Diesel cycle, of which this is an example, burning must be delayed over a period of time.

BY MR. BEAN:

Q I think it might be helpful, Mr. Brush, if you would follow me in a non-technical explanation of the difference between an Otto cycle and a Diesel type ignition or burning.

In the Otto cycle, and see if I state it correctly, a fuel charge is brought into the cylinder in that entire area, and it is mixed as completely as possible with the air in the space above the cylinder and then compressed. Near the time when it reaches the point of greatest compression, when the piston is near the top, a spark plug brings about the operation of a spark, which starts an explosion
or rapid burning or combustion in that mixed fuel.
132 Is that a correct description of the Otto cycle type
of combustion?

A That is correct.

Q Now, in the Diesel, straight Diesel type of combustion, in the first place, there is usually no spark plug?
A No.

Q There is no spark plug and air is drawn into the portion of the cylinder above the piston, that is, a complete charge of air is always brought into the Diesel operation? A That is correct.

Q And the piston comes up, and as the piston is brought up in the cylinder, the pressure is raised in that air to quite a high point? A That is right.

Q And when it reaches practically its highest point, then fuel is injected into the cylinder and the chamber inside is so hot that spontaneous combustion or burning starts as soon as the fuel hits and starts this burning; is that correct? A Right.

Q And then continued injection of fuel as the piston is going down continues to help the air to expand and to drive the piston down? A That is right. In addition,
perhaps I should add that the intent is to burn the
133 fuel in a Diesel engine slowly enough so that the
pressure never rises materially above the compression of the power air charge.

Q Is that the reason why in Diesel construction you do not have a homogeneous mixture of fuel and air prior to or at the time of ignition? A That is precisely the major reason. If a homogeneous mass of fuel and air were in there, I would not want to say how high that pressure would rise, four or five hundred pounds or more per square inch of a homogenous charge fired, well, it just would be impractical to make an engine strong enough to stay together.

Q. Now, Mr. Brush, in this Werner patent, do you find any teaching or any suggestion of the Broderson method that you have previously described here? A I do not.

Q Now, the Patent Office in the Board of Appeals has stated with respect to this particular Werner patent, on page 5 of its decision: "We find the method recited in Claim 1 disclosed in the Werner patent so that the claim is unpatentable over that patent without the use of any auxiliary reference."

Now, keeping that statement in mind, Mr. Bush, and reading a portion of Claim 1 to you, I will then ask your opinion with respect to it.

In Claim 1, it is stated as part of the method:

134 "Injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber."

Do you find that portion of the method of Claim 1 that I have just quoted either taught or suggested in the Werner construction or method? A It is not; no part of it.

Q I will just ask you this question. It is possibly unnecessary.

In Werner, is there any controlled stratification, Mr. Brush? A No.

Q It was stated in counsel for defendant's opening statement that the defendant considered these three patents that we have discussed as being representative of the best prior art available against the Broderson application.

But there were a number of other patents, prior art patents, cited in the answer in this case, and they have been offered in evidence here.

Have you read and are you familiar with those other prior art patents? A I have read them and I am familiar with them.

135 Q Are you in agreement or disagreement with the position of the defendant that the three patents discussed here are representative of the most pertinent prior art of all of those that have been considered? A I am in full agreement with that statement.

Q Now, Mr. Brush, I will ask you this question, and without mentioning each of the patents by name or number, in the other prior art patents which are in evidence in this case, other than the three that you have discussed, are there any of those patents taken by themselves which, in your opinion, either teach or suggest the method claimed by Mr. Broderson in this application of his? A It is my considered opinion that none of them either disclose or suggest the Broderson method as pointed out in the claims here at issue.

Q And is there any teaching to you as a skilled mechanic whereby a combination of those prior art patents, which have not been discussed or which have been discussed here, would either teach or show the Broderson invention? A There is not.

Q In the decision of the Board of Appeals in this case, on page 6, Mr. Brush, it is stated:

"We do not find Claim 1 to distinguish from the prior art by reason of the effect of the recitation of the relation of the quantity of fuel charged at the various times
136 in the cycle."

In your opinion, does the quantity of fuel charged at various times in the cycle of the Broderson method, is that of imporance? A It certainly is.

Q And is the possibility of varying the relationships of these quantities of fuel as taught by Broderson, in your opinion, of any importance? A It is highly important.

MR. BEAN: That completes the direct examination, Your Honor.

MR. MOORE: I have no cross examination, Your Honor.

(Thereupon the witness was excused and retired from the witness stand.)

MR. BEAN: Your Honor, I would like to offer in evidence, as illustrative only, the charts which Dr. Conta used as plaintiff's exhibits number 2 through 7, inclusive.

THE COURT: Very well. They will be admitted.

MR. BEAN: Thank you, Your Honor.

(The documents previously marked for identification as Plaintiff's Exhibits 2 through 7, respectively, were received in evidence.)

MR. BEAN: Now, what are Your Honor's wishes with respect to the closing of this matter? Would you like oral argument or briefs?

137 THE COURT: I prefer briefs.

MR. BEAN: Thank you.

THE COURT: I can take the briefs and take my time in going over them better than I can here to hear oral argument.

MR. BEAN: I would like very much to be permitted to submit a brief, Your Honor.

THE COURT: I really think the examination of the witnesses has been in the nature of oral argument.

MR. BEAN: I hope I did not transgress.

THE COURT: No, I did not mean that. Necessarily it is equivalent to argument in a way.

MR. MOORE: I wondered at several points whether I should cross examine counsel or not.

THE COURT: You may answer his brief and it may take the place of cross examination.

MR. BEAN: Do you have any wishes in regard to the time, Your Honor?

THE COURT: The main thing I have in mind is for you not to delay too long. I much prefer to take it up while I have it fresh in my mind and not wait until I have forgotten about it and have to go over it again.

MR. BEAN: I understand from the reporter that it will possibly be two weeks before I get the transcript of the testimony. Might I have time to put in our brief—this is the 3rd, until the 10th of next month?

138 THE COURT: Very well.

MR. BEAN: That will be the 10th of December.

MR. MOORE: Then could the defendant's brief be delayed until the first of next year? I presume you won't be sitting during the holiday.

THE COURT: I might use part of my time for this case.

MR. MOORE: I think I can get the brief in within 15 days after I receive his.

THE COURT: Can you do it in less time than that?

MR. MOORE: Ten days?

THE COURT: Yes.

MR. MOORE: Very well. I will do that.

MR. BEAN: Thank you very much, Your Honor, for your consideration.

(Thereupon the instant hearing was concluded.)

Jan. 3, 1939. F. C. MOCK **2,142,280**

INTERNAL COMBUSTION ENGINE

Filed June 29, 1933

Fig. 1

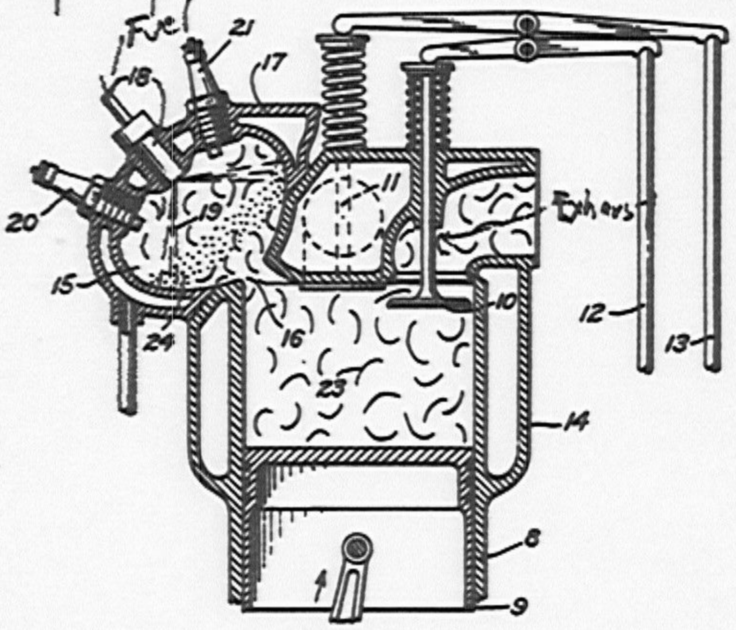


Fig. 2

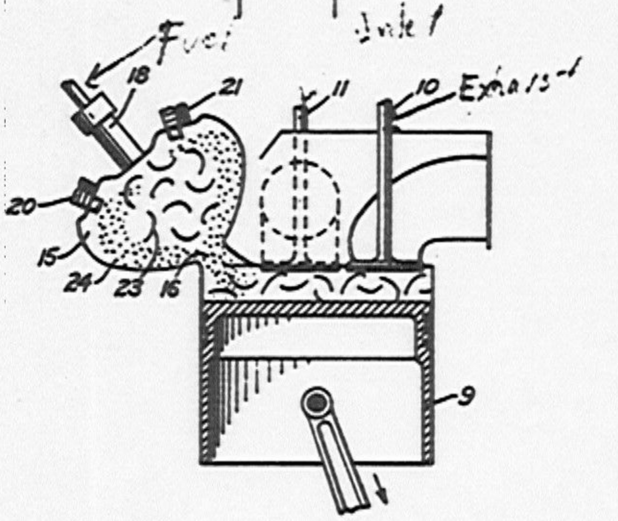


Fig. 4

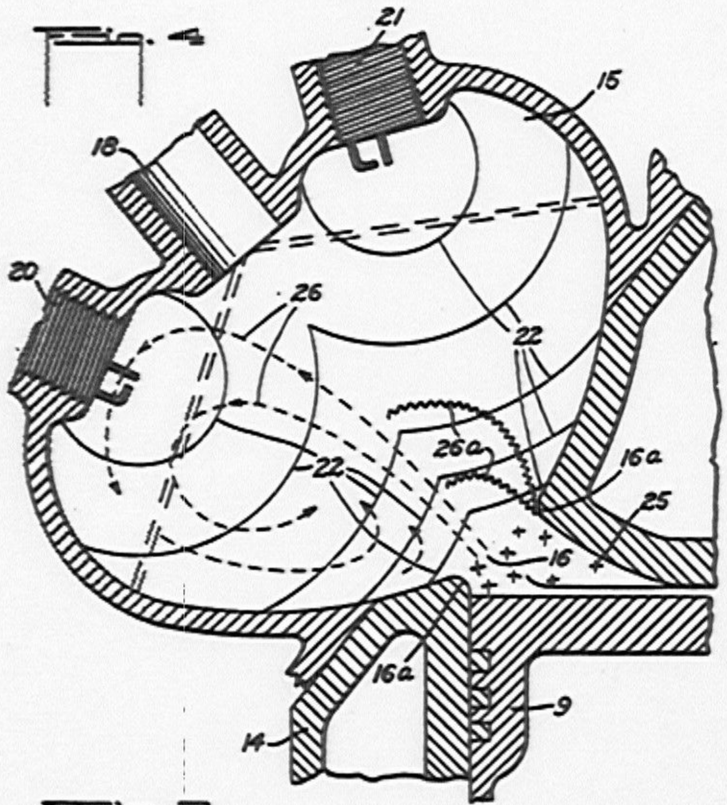


Fig. 3

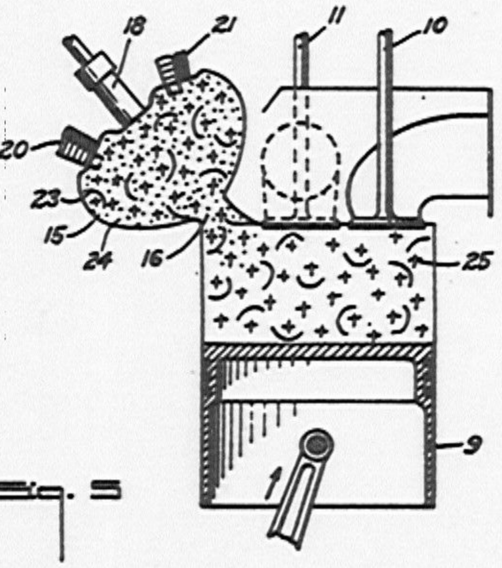


Fig. 5

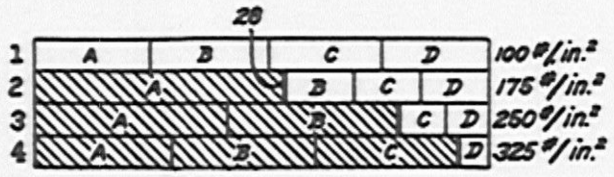
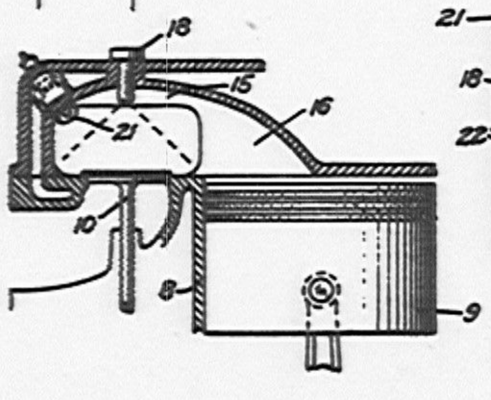


Fig. 6



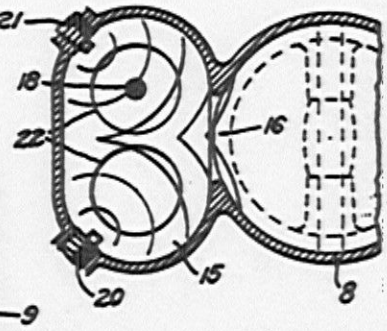


Fig. 7

INVENTOR.

Frank C. Mock

BY Warren T. Hunt

ATTORNEY.

UNITED STATES PATENT OFFICE

2,142,280

INTERNAL COMBUSTION ENGINE

Frank C. Mock, Montclair, N. J., assignor to
Eclipse Aviation Corporation, East Orange,
N. J., a corporation of New Jersey

Application June 29, 1933, Serial No. 678,277

2 Claims. (Cl. 123—32)

This invention relates to internal combustion engines and more particularly to engines of the liquid fuel injection type.

In engines of the above type heretofore utilized, considerable difficulty has been encountered in securing relatively rapid and complete vaporization of the injected fuel and efficient combustion of the resultant fuel mixture without obtaining detonation and its accompanying disadvantages, especially in that type of engine where relatively high compression ratios are desired to be attained.

One of the objects of the present invention is to provide a novel internal combustion engine so constructed as to avoid the above mentioned difficulties.

Another object of the invention is to provide in an internal combustion engine, a novel method and means for introducing the fuel therein whereby a more rapid and complete vaporization of the fuel will occur, and wherein the combustion thereof will be effected in such a manner that detonation and rough running of the engine will be avoided.

Still another object is to provide in an internal combustion engine of the above character, a novel construction whereby the combustible mixture is formed and initially ignited without the engine cylinder, the burning of the mixture being accompanied by a flame having a substantially spherical wave front which proceeds in such a manner as to encounter a relatively non-homogeneous mixture of fuel vapor and air prior to reaching the engine cylinder, thereby materially decreasing the tendency for spontaneous ignition of any portion of the mixture, which might cause detonation.

A further object is to provide in an engine of the above type, a novel combustion chamber construction wherein the fuel is initially conducted and wherein ignition of the fuel charge occurs in such a manner as to avoid the possibility of the flame front of the burning charge trapping explosive mixture against a wall where such mixture might be detonated by compression.

A further object is to provide a novel method of timing and directing the injection of fuel into an engine of the above character whereby a more complete vaporization of the fuel will be obtained and ignition and combustion of the fuel may be effected in a highly efficient manner and without obtaining detonation.

A still further object is to provide a novel internal combustion engine having a relatively high compression ratio which may be operated without detonation and yielding a materially higher fuel efficiency with relatively lower stresses and weight than has heretofore been obtained.

Other objects and novel features of the invention will appear more fully hereinafter from the following detailed description when taken in connection with the accompanying drawing, wherein the invention is illustrated as being embodied in several forms. It is to be expressly understood, however, that the drawing is for purposes of illustration only and is not designed as a definition of the invention, reference being had for this purpose to the appended claims.

In the drawing:

Fig. 1 is a vertical section of an internal combustion engine cylinder construction embodying the present invention;

Fig. 2 is a diagrammatic view of the parts shown in Fig. 1 and illustrating the condition of the fuel charge during the working stroke with both inlet and exhaust valves closed;

Fig. 3 is a diagrammatic view similar to Fig. 2 showing the condition of the fuel charge during the compression stroke;

Fig. 4 is an enlarged sectional view of the combustion chamber showing the condition of the fuel charge shortly after ignition;

Fig. 5 illustrates an explanatory chart of pressures developed after ignition of various portions of a fuel charge;

Fig. 6 is a partial sectional view of the invention applied to an L-head engine; and

Fig. 7 is a horizontal partial sectional view of the parts shown in Fig. 6.

In order to understand at the outset, one of the principles of operation of an internal combustion engine, and with which the present invention is associated, reference will be had to the illustrative chart of Fig. 5 wherein it may be assumed that any one particular charge of combustible mixture is divided into four equal portions, A, B, C and D, line 1. The latter represents these four portions of the charge as being of equal volume, prior to ignition and after having been compressed to a pressure of 100 lbs. per square inch. After portion A has been ignited and burned, as indicated at 28 and by the shaded area A of line 2, the pressure rises to 175 lbs. per square inch and the volume of portion A has increased while the combined volume of portions B, C and D has decreased. Line 3 indicates the relative volumes of the various portions of the charge after portion B has also been ignited and burned, it being noted that the pressure has risen to 250 lbs. per square inch, while line 4 shows the condition of the charge after portion C has been ignited and burned. It will be appreciated from a consideration of the latter, that the unburned portion D is of relatively small volume and under a relatively high pressure, 325 lbs. per square inch, as indicated. From the latter, it will also be appreciated that spontaneous combustion of the last portion D under such high pressure may produce detonation, it having been determined that the spontaneous combustion of portion D under high pressure, and especially if trapped against a wall of the combustion chamber, will effect a rapid persisting reciprocating movement of flame throughout the combustion space, generating waves of high pressure and luminosity which initiates detonation both directly and secondarily by heating the walls of the combustion chamber to a relatively high temperature.

In eliminating the above described undesirable condition, the present invention embodies, among other features, two principles, namely that upon burning of fuel, the flame propagation of the burning mixture proceeds from the point of ignition outwardly with a substantially spherical wave front; and that combustion and spontaneous ignition of a lean or poorly diffused mixture of fuel vapor and air is slower and more difficult than with a finely divided homogeneous mixture.

Referring to Fig. 1, an internal combustion engine constructed in accordance with the present invention is illustrated therein as being constituted by a cylinder 8 having a piston 9 reciprocatingly mounted therein. Exhaust gas and air inlet valves 10 and 11 respectively are provided in the cylinder head and suitable actuating means 12 and 13 are employed for operating said valves, as well understood in the art. A jacket 14 preferably surrounds the cylinder 8 and a suitable cooling medium may be circulated therein for the purpose of cooling the walls of the cylinder.

The present invention, as heretofore pointed out, is particularly concerned with a method and means for vaporizing and igniting the fuel charge for the purpose of eliminating detonation and to this end there is provided a suitably shaped combustion chamber 15 secured to but offset from said cylinder, and communicating with the latter through a restricted opening 16. In the form shown, the chamber 15 is heart-shaped, but it will be understood that any suitable form may be employed, it being necessary only that the form be such as to prevent the trapping of a portion of the charge against a wall of the chamber by the advancing spherical flame wave front. Preferably, the chamber is provided with means whereby its walls may be maintained at a higher temperature than is necessary for the piston travelled walls of the cylinder. For example, a jacket 17 may be provided in which a suitable liquid, such as triethyl glycol may be circulated. It will be noted from the latter that the walls of the chamber 15 are of such contour that the advancing flame front always encounters such walls obliquely by which arrangement the possibility of trapping explosive mixture against a wall of the combustion chamber, which might cause detonation if spontaneously ignited, is avoided.

In operation of that form of the invention illustrated in Figs. 1 to 4, and referring to Fig. 1, it will be apparent that fuel may be injected into chamber 15 through the nozzle 18 during the late exhaust or early intake strokes of the piston, the requirement being that the fuel must not enter too greatly into the piston displacement chamber. In certain instances, it may also be desirable to inject a portion of the fuel charge insufficient of itself to propagate combustion, early in the cycle, as for example during the intake stroke, and then inject the remainder of the fuel charge just prior to ignition. Such a procedure would favor more complete evaporation and mixture of the fuel and air than might otherwise occur if all of the fuel were injected just prior to ignition.

Since injection of fuel under any of the above circumstances takes place in a chamber relatively isolated with respect to the engine cylinder, it will be appreciated that a greater interval of time is permitted for vaporizing the fuel, thus effecting a greater degree of vaporization than has heretofore been obtained, and especially is this true when the fuel is injected during the late exhaust or early intake strokes of the piston. Under the latter condition, a mixture, vaporized to a relatively high degree, is obtained prior to the occurrence of ignition.

Referring again to Figs. 1 to 4 and considering that injection of fuel is occurring during the exhaust stroke, the combustion chamber will be filled with hot exhaust gases, as indicated by short curved lines 23, the heat of which will assist in vaporizing the injected fuel indicated by the dots 24. The relative positions of the fuel vapor 24 and the exhaust gases 23 in the combustion chamber 15 after completion of the exhaust stroke and just prior to opening of the intake valve is illustrated in Fig. 2, while Fig. 3 illustrates, during the compression stroke, the intimate commingling of the fuel vapor, a slight amount of exhaust gases, together with air, indicated by the crosses 25, which was drawn into the cylinder during the suction stroke.

Fig. 4 illustrates diagrammatically the conditions in the combustion chamber after the compression stroke, during which air alone has been forced into the heart-shaped chamber 15 to effect an irregular vortex of fuel vapor in each half of the chamber, as indicated by the lines 26. Such turbulence is materially aided by providing the opening 16 communicating the chamber 15 with the cylinder 8 with relatively sharp entrance walls 16*a*. It will also be noted, as heretofore pointed out, that when ignition occurs the spherical wave front 22 of the flame due to the burning of the combustible mixture will be propagated from each of the ignition devices 20 and 21 toward the opening 16 somewhat modified by the mass motion existing in the gaseous charge. It is to be particularly noted that initially the flame front encounters a well vaporized combustible mixture and an efficient burning of the fuel is effected. However, as the flame fronts approach the opening 16, a less combustible mixture is encountered due to the passage of air alone, 25, into said chamber during the final part of the compression stroke, Fig. 3, the air being probably in the form of jets 26*a* adjacent the opening 16. Thus the flame fronts lastly encounter a mixture largely composed of air, just prior to entry into the cylinder 8 during the working stroke, which mixture is relatively non-combustible, and this feature effects a substantial elimination of the possibility of detonation, as heretofore pointed out. As shown in this figure, fuel injection may occur during the compression stroke.

A modified form of the invention enabling the utilization of the principles herein described with an L-head engine is disclosed in Figs. 6 and 7, wherein it will be noted that fuel injection occurs in an offset chamber 15 through the nozzle

18 directly on to exhaust valve 10. The ignition devices 20 and 21 as heretofore, are so located in the chamber that the direction of propagation of the spherical wave fronts of the burning mixture will be towards the opening 16 communicating the chamber with the cylinder 8 as indicated at 22, Fig. 7.

From the above, it will be appreciated that there is provided by the present invention, a novel internal combustion engine which is so constructed and arranged as to enable high compression ratios to be utilized and wherein unusually high fuel efficiencies may be realized. The provision of the combustion chamber relatively remote from the engine cylinder and the manner in which fuel is injected therein results in a more complete vaporization of the fuel than is possible in engines of the compression ignition or Diesel types.

The location of the ignition devices employed in connection with the combustion chamber is such that the wave fronts of the burning gases are directed towards the opening communicating said chamber with the engine cylinder and the combustion flame encounters a relatively lean mixture of fuel and air just prior to entry of the flame fronts into the last portion of the enclosed space in said chamber, this arrangement avoiding the possibility of any spontaneous combustion of the portion of the charge under high pressure, which might otherwise cause detonation and high pressure high temperature waves.

While several embodiments of the invention have been disclosed and described herein, it is to be understood that the same is not limited thereto but may be embodied in other forms as well understood by those skilled in the art, without departing from the spirit of the invention. Reference will therefore be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. In an internal combustion engine having a cylinder and a piston, a combustion chamber of heart-shaped form offset from said cylinder, said chamber and cylinder communicating through a restricted opening positioned between the cylinder and the apex of said heart shaped chamber, fuel injection means in said chamber positioned in the wall of said chamber opposite to said opening, said fuel injecting means being arranged to direct fuel into said chamber, and ignition means disposed upon each side of said fuel injecting means and arranged adjacent thereto.

2. In an internal combustion engine having a cylinder and a piston reciprocating therein, a combustion chamber communicating with said cylinder through a restricted opening, said chamber being of heart-shaped form and being offset from said cylinder, fuel injecting means remote from said opening and positioned in the wall of said chamber opposite to said opening, said fuel injecting means being arranged to direct fuel into said chamber, and ignition means symmetrically disposed on each side of said fuel injecting means and arranged adjacent to said injecting means to direct the spherical wave front of the flame due to ignition of the fuel towards said opening.

FRANK C. MOCK.

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O. WERNER

INTERNAL COMBUSTION ENGINE

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Fig. 2.

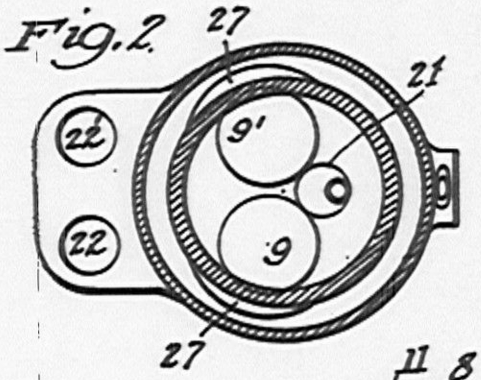


Fig. 3.

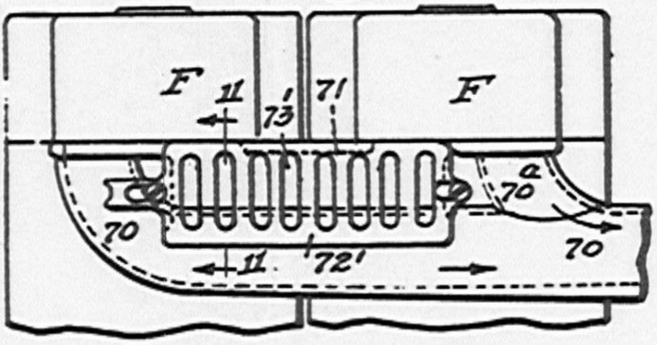


Fig. 4.

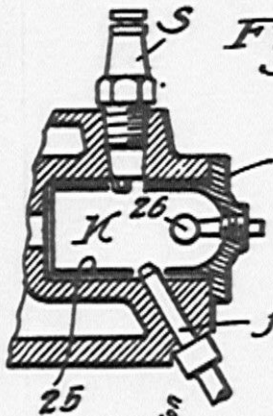


Fig. 1.

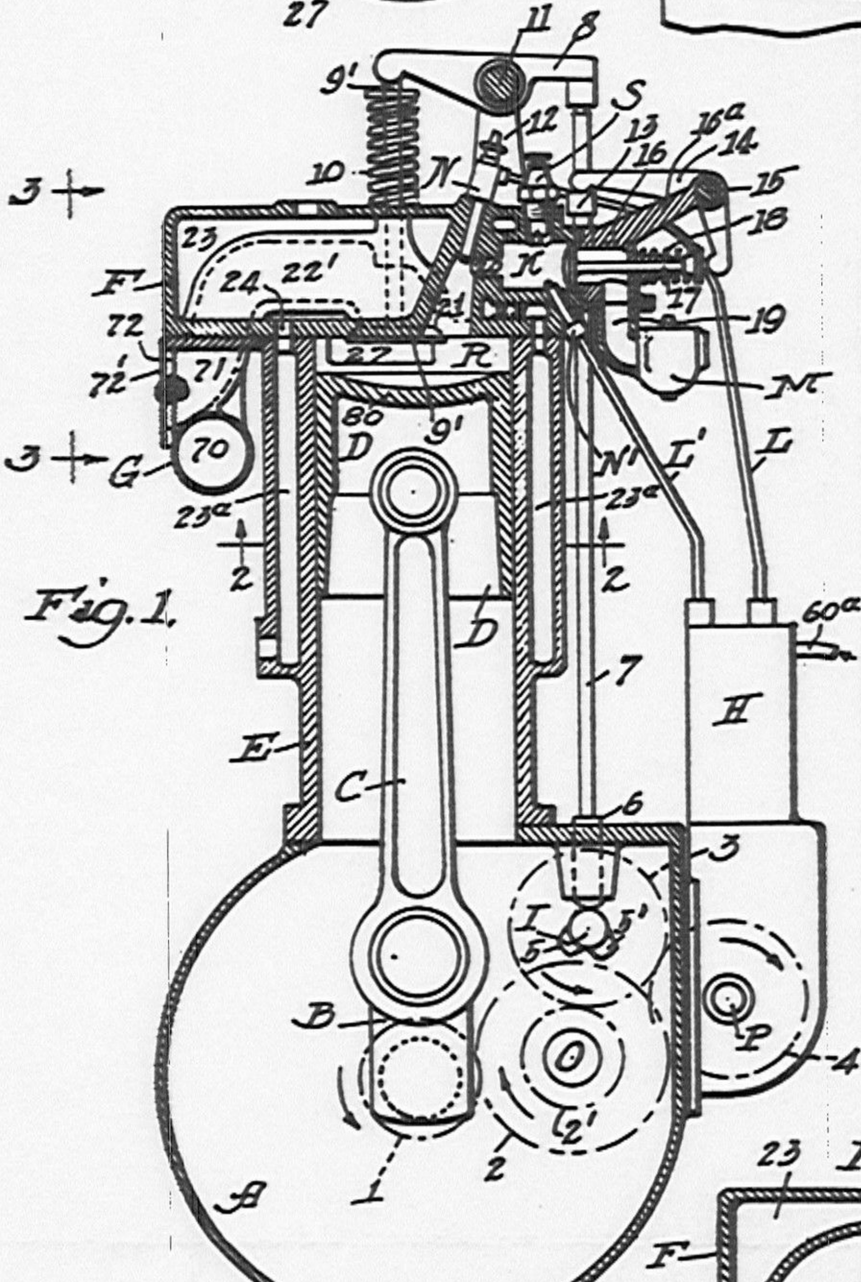


Fig. 5.

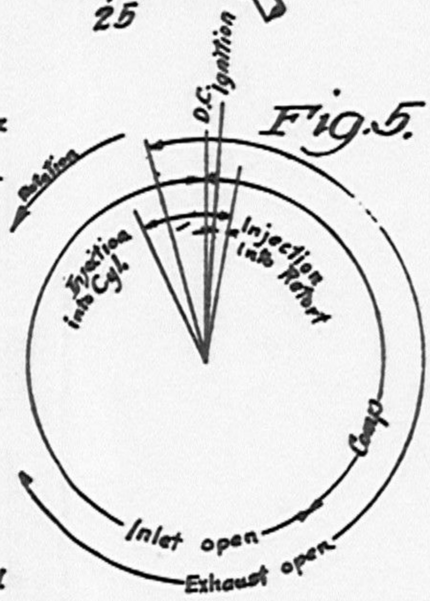
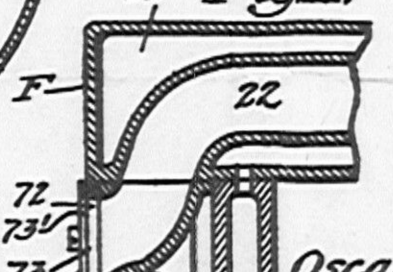


Fig. 11.



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INTERNAL COMBUSTION ENGINE

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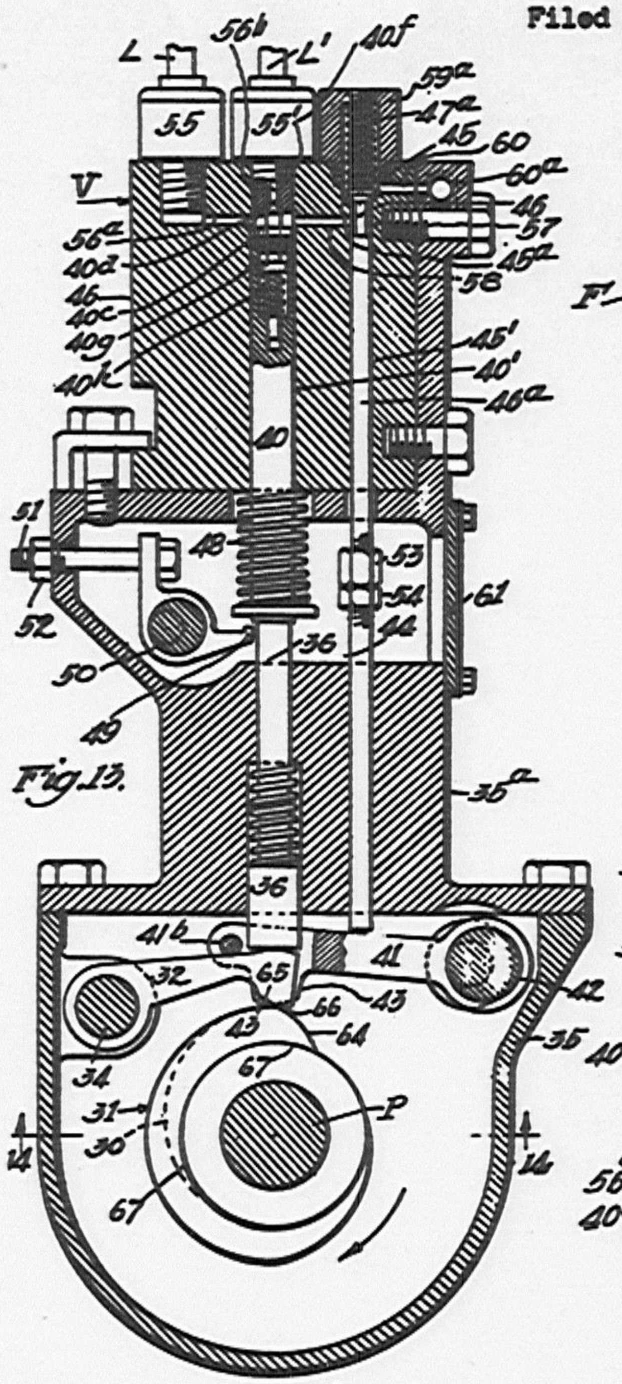


Fig.13.

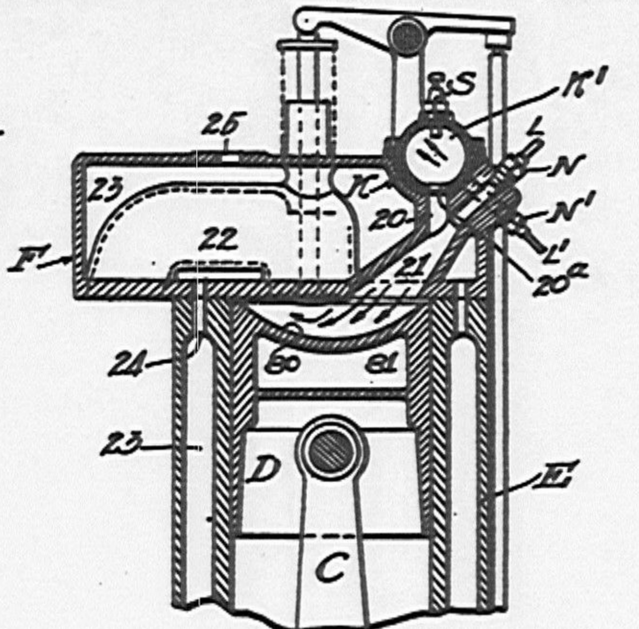


Fig.16.

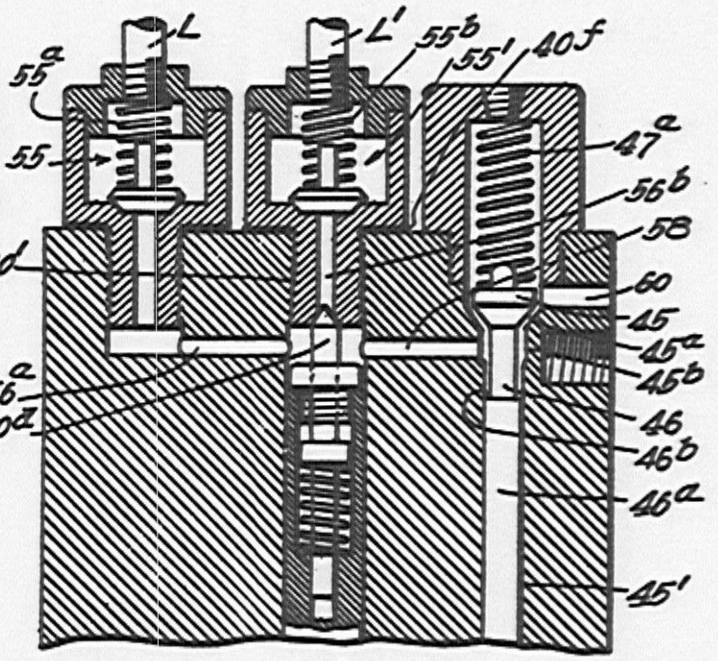
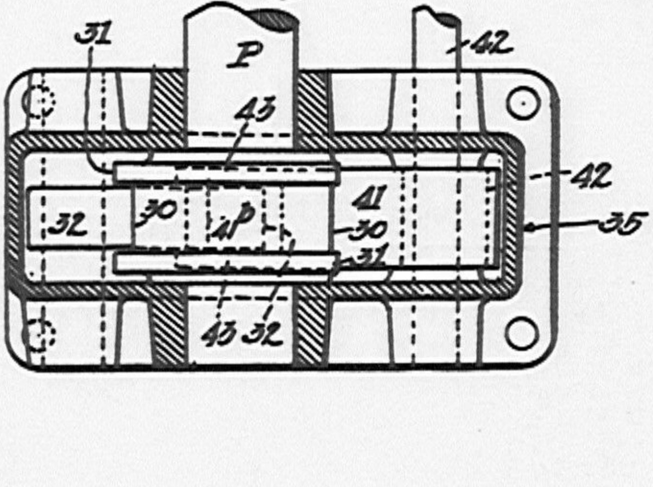


Fig.15.

Fig.14



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Feb. 1, 1927. **1,616,157**

O. WERNER

INTERNAL COMBUSTION ENGINE

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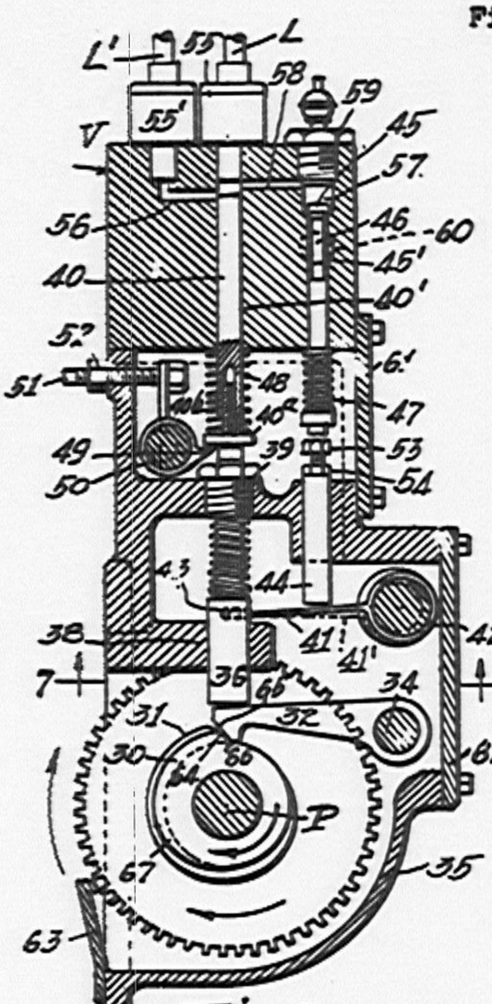

Fig.6.

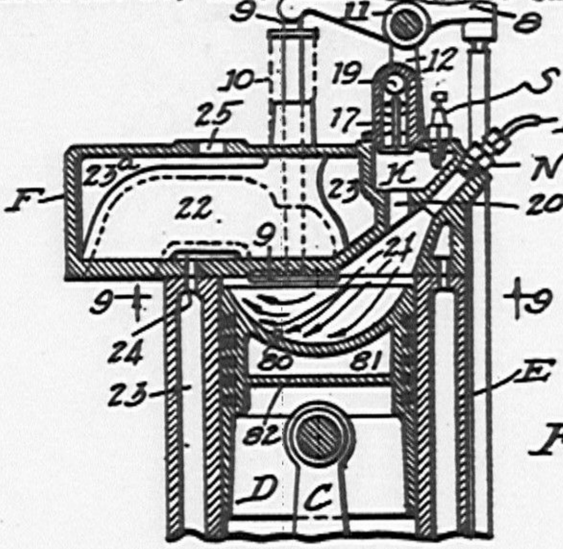

Fig.8.

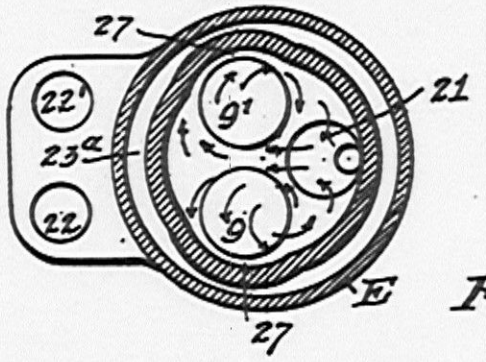

Fig.9.

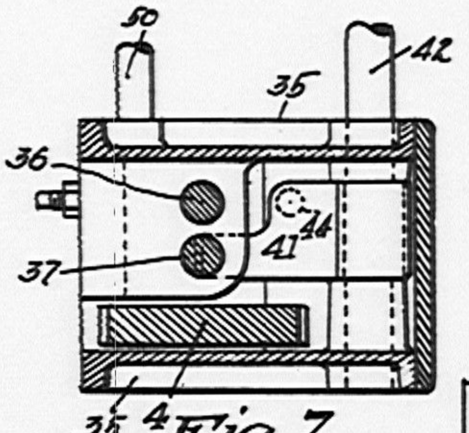

Fig. 7.

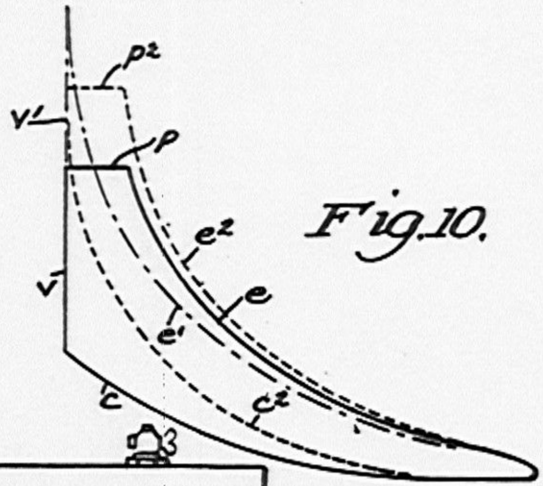

Fig.10.

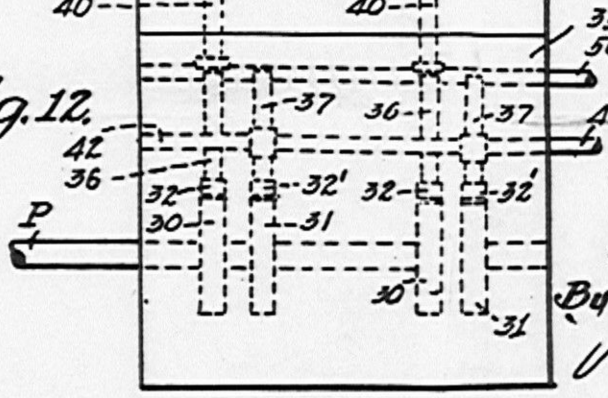

Fig.12.

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Patented Feb. 1, 1927. **1,616,157**

UNITED STATES PATENT OFFICE.

OSCAR WERNER, OF BRIDGEPORT, CONNECTICUT.

INTERNAL-COMBUSTION ENGINE.

Application filed February 15, 1923. Serial No. 620,262.

This invention relates to an internal combustion engine of the type provided with ignition chamber or retort wherein is adapted to be created an initial explosion the flaming gases of which are adapted to enter a combustion chamber to there ignite and cause to be burned fuel deposited in said combustion chamber.

It is an object of the invention to provide an engine of the present character having novel mechanism whereby fuel can be admitted to its combustion chamber at the time of, before, and after initial ignition in a retort associated with said combination chamber so that the fuel that is admitted at the time of or before said initial ignition may burn at substantially constant volume, as in the Otto cycle, and that admitted after said initial ignition may burn at substantially constant pressure, as in the Diesel cycle, and to provide an interrelated and communicating combustion chamber and ignition chamber or retort so constructed, and arranged with respect to each other, that the ignition and burning of the fuel in the combustion chamber will be certain and accurate no matter whether the admission or injection of the fuel to said combustion chamber is at the time of, before, or after the ignition of the fuel in the ignition chamber or retort and its propagation into the combustion chamber.

To the accomplishment of this object accurate and effective controls for the admission or injection of fuel, including controls for a total amount, its timing, and the proportioning of the amounts introduced before and after initial ignition, are provided. The control for said proportioning of the amounts of course controls the proportionate amounts of fuel burned at constant volume and at constant pressure, and in this connection I may also state that I preferably provide my control means in such a manner that, the various controls having been once set to suit the particular type of engine, its average power output, etc., the variations in the output are then controlled by varying the amount of fuel burned at constant pressure without varying the amount burned in constant volume.

There are various other objects and corresponding advantages and accomplishments of the invention which will become apparent from the full description of the structure and operation of a specific form of engine in which the features of the invention are incorporated now to be made, it being understood that the disclosure herein is merely illustrative and meant in no way in a limiting sense, changes in details of construction and arrangement of parts being permissible so long as within the spirit of the invention and the scope of the appended claims.

Fig. 1 shows a vertical section of a preferred construction of the engine;

Fig. 2 shows a horizontal section on line 2—2 of Fig. 1 with manifold and various other parts removed;

Fig. 3 shows a side view of the manifold attached to a two cylinder engine;

Fig. 4 is a detail section showing a modified form of retort;

Fig. 5 shows a typical valve opening, fuel injection and ignition timing diagram based on the angular travel of the crankshaft;

Fig. 6 shows a vertical section through the fuel pump for a one cylinder engine;

Fig. 7 shows a horizontal section on line 7—7 of Fig. 6;

Fig. 8 is a vertical section showing another construction of cylinder head and retort;

Fig. 9 shows a horizontal section on line 9—9 of Fig. 8;

Fig. 10 shows an ideal indicator diagram of the cycle described, compared with indicator diagrams of the Otto cycle and the Diesel cycle;

Fig. 11 is a detail section on line 11—11 of Fig. 3;

Fig. 12 is a diagrammatic view showing how the pump is applied to a multi-cylinder engine;

Fig. 13 is a view similar to Fig. 6 showing a modified form of fuel pump;

Fig. 14 is a section on line 14—14 of Fig. 13;

Fig. 15 is a sectional enlargement of certain parts shown in Fig. 13, and also showing a small variation; and

Fig. 16 is a view similar to Fig. 8 showing another modification of cylinder head and retort.

A denotes the crankcase, B the crankshaft, C the connecting rod, D the piston, E the cylinder, F the cylinder head, G the inlet and exhaust manifold, H the fuel pump, I the camshaft, K the retort, N the main fuel nozzle, N′ the auxiliary fuel nozzle, L the fuel lead from pump H to nozzle N, L′ the fuel lead from pump H to auxiliary nozzle N′, M the auxiliary carbureter. Camshaft I is driven through gear 1, mounted on the crankshaft B, idler gears 2 and 2′ mounted on idler pinion O and gear 3, mounted on camshaft I in such a way as to rotate at one half crankshaft speed. Fuel pump H is bolted to crankcase A and driven at camshaft speed through gear 4, mounted on fuel pump shaft P and engaging with gear 3. On camshaft I is mounted cam 5 which through tappet 6, pushrod 7, and valve rocker 8 operates main inlet valve 9; the exhaust valve 9′ being operated by a like mechanism from cam 5′. Valve spring 10 has the usual function. Rocker-arm 8 oscillates around shaft 11 which is supported by uprights 12 mounted on cylinder head F.

The pushrod 7 operating the inlet valves carries adjustable block 13 which operates offset bellcrank 14 carried by pin 15 mounted on an extension 16^a of auxiliary inlet valve cage 16. Bell crank 14 opens valve 17 against pressure of the valve spring 18. Thus auxiliary inlet valve 17 is operated in conjunction with main inlet valve 9, but by allowing an extra amount of clearance between bell crank 14 and valve 17, said valve 17 can be made to open later and close earlier than valve 9. Also by this method the total lift of valve 17 can be decreased. Inlet valve cage 16 communicates through passage 19 with auxiliary carbureter M which is supplied with a fairly volatile fuel such as gasoline or kerosene. (In case of a multi-cylinder engine, one carbureter can be used to supply two or more cylinders.) The engine is shown at the end of its compression stroke with all valves closed. The auxiliary inlet valve 17 opens into retort K into which also opens spark plug S and auxiliary fuel nozzle N′. Spark plug S is connected with a source of igniting current, so timed as to create ignition when the piston reaches the top dead center or just previous thereto. At its other end retort K is in constant communication with compression space R through passage 20 which communicates with the upper end of funnel shaped passage 21. This passage 21 is so located as to point down more or less vertically and to terminate at its lower end more or less centrally with reference to compression space R. Fuel nozzle N is so located that its axis approximately coincides with the axis of passage 21.

Fuel nozzles N and N′ may be of any of the various forms commonly used in Diesel or semi-Diesel engines for the purpose of emitting the fuel in a cone or fine spray.

Valves 9 and 9′ communicate with manifold G through passages 22 and 22′.

Presuming the use of auxiliary carbureter M (in which case nozzle N′ and fuel line L′ are not being used) the operation of the engine is now as follows: ①

During the suction stroke of the engine valves 9 and 17 are held open by cam 5 and connecting linkage 6, 7, 8, 13 and 14. The piston D being on its downward stroke will suck pure air through manifold G and passage 22 past valve 9 into compression space R. At the same time there will enter a small amount of carburetted mixture from carbureter M through passage 19 and past valve 17 into retort K, by reason of the vacuum existing within the cylinder being communicated to the retort through passages 20 and 21.

Portion of fuel during suction

2

On the compression stroke all valves being closed, the air in compression space R will be compressed to the desired pressure and this pressure will be communicated through passages 21 and 20 to retort K compressing the carburetted mixture therein to substantially the same pressure that exists within the cylinder.

Shortly before the piston reaches the top center of its stroke (about 10° previous thereto) fuel injection will begin and fuel will be sprayed from nozzle N in a fine continuous spray into channel 21 and into space R and toward the head of piston D. The piston head may be utilized for promoting the vaporizing of the fuel either by actual contact with the fuel spray or by heat radiation. The spray entering the main cylinder will mix with the compressed air present there and form a mixture too lean to be ignitible by ordinary means. The mixture, however, will be quite rich within passage 21 where the fuel spray was well confined. Just before the piston reaches upper dead center (in practice about 5° previous thereto), spark plug S will ignite the carburetted mixture in retort K. Due to the turbulence set up therein by the jet of compressed air that has rushed into the retort during the compression stroke through comparatively small passage 20, a very rapid and violent explosion will follow. The flaming gases will rush from the retort through passages 20 and 21 into space R with great force and set up within space R a violent turbulence. They will encounter on their way and ignite the comparatively rich heavy fuel mixture within passage 21, (the injection of heavy fuel going on uninterruptedly at this time), and their combined heat will raise the temperature within combustion chamber R sufficiently to readily ignite the lean fuel mixture encountered there. Up to this point the combustion proceeds at constant volume as in the Otto cycle, but due to the average leanness of the mixture the ratio of the pressure rise within combustion chamber R will be much less than in the Otto cycle. Also on

Fuel injection during compression

Ignition

account of the average leanness of the mixture the likelihood of fuel knock will be overcome.

Thereafter any fuel spray entering from nozzle N upon striking the flaming gases there present within space R will be vaporized and ignited almost instantly and due to the high degree of turbulence then existing within space R they will be thoroughly intermingled with the gases therein, thus increasing the rate of flame propagation and tending towards a clean combustion and the fullest utilization for combustion purposes of the available air. With proper design of the fuel pump the rate of fuel injection is such as to maintain the pressure in the cylinder approximately constant as long as the injection lasts, despite the outward travel of the piston. It will thus be seen that the heavy fuel injected into the cylinder previous to ignition will burn at constant volume, while the heavy fuel injected thereafter will burn at constant pressure as in the Diesel cycle. The proportion between the amount of fuel to be burned at constant volume and the amount of fuel to be burned at constant pressure can be regulated at will and within wide limits by changing the interrelation between the timing of the fuel injection and the timing of the spark.

The output of the engine can be reduced by decreasing the rate of fuel discharge or preferably by cutting off the fuel injection at an earlier point, thereby reducing the amount of fuel burned at constant volume or eliminating it entirely. Any further cutting off of the fuel injection will result in producing a still leaner mixture within the compression space previous to explosion, thereby still further reducing the output of the engine. The nature of this mixture can also be influenced to a certain extent by altering the point of beginning of the fuel injection.

Thereafter, (after fuel injection cutoff) and upon further outward travel of piston D, the gases within the chamber R will expand in the usual manner. Toward the end of the outward stroke, valve 9′ is opened through cam 5′ and thereafter during the exhaust stroke following the gases will rush through passage 22′ into exhaust manifold G in the usual manner.

In Fig. 10 I have shown various superimposed ideal indicator diagrams. The above described cycle follows the solid outline c, v, p, e. Outline c, v, v', e', is the indicator card of an Otto cycle using the same compression pressure. Outline c_2, p_2, e_2 is the indicator card of the Diesel cycle.

It will be noted that due to the leanness of the mixture at the time of ignition the maximum explosion pressure is considerably less than that of an Otto engine employing the same compression, (the pressure used being 2 to 2.7 to 1 against 3.75 to 1 in the Otto engine). It will also be noted that the maximum pressure is less than in the Diesel cycle, which requires high compression in order to produce a temperature high enough for self-ignition.

In Figs. 8 and 9 I show a variation of the arrangement shown in Fig. 1. The outstanding differences in Figs. 8 and 9 are a greater inclination of nozzle N and passage 21 and a widening of the throat of passage 21 so that it is more expansive. In this arrangement the retort K, valve 17, and spark plug S have been somewhat changed in position for convenience of design; they operate the same as hereinbefore described. Also the head 80 of the piston is cupped out more deeply than in Fig. 1; and this, together with the more angular position of passage 21, causes the spray to hit more nearly to the center of the piston and makes the length of the spray, before it hits the piston head, as long as possible. It has been found that not only the width of the spray cone and the relative dispersion of the spray particles, but also the fineness of the spray increases with the distance.

Also the further depression of the piston head, in addition to lengthening the spray distance without increasing the compression space, has the effect of bringing up the sides of the piston so as to practically completely cover the cylinder walls when the piston is in its uppermost position. The spray thus cannot hit the cylinder walls to interfere with cylinder lubrication. It has been found desirable to have the piston hot enough so that any particles of fuel spray not previously nebulized, or vaporized, are evaporated immediately when they hit the piston; and it is at the same time desirable to have the piston head cool enough as to not cause dissociation of the fuel into lampblack and lighter hydrocarbons.

After considerable experimentation and trial, the specific design shown in Fig. 8 has been adapted to accomplish the foregoing desirable features. I also leave the upper surface of head 80 unfinished so as to increase the heat absorption from the hot gases, and I provide a baffle plate 82 (either cast integrally or formed by sheet metal) to form a confined air space 81 and prevent oil splash or air currents from coming into contact with head 80 and carrying off its heat.

In addition to the advantages above set forth, the thermal efficiency of the engine is also increased by cutting down the heat that is lost to the usually uncovered walls, and to the usually comparatively cold type of piston head.

In Figs. 8 and 9 the valves 9 and 9′ are set over a little further from the cylinder center so as to allow room for the enlarged passage 21 and to get that passage near to the center.

The explosive mixture within retort K can be produced by various means, for instance; instead of using auxiliary carbureter M, a small portion of fuel can be injected into the retort toward the end of the compression stroke and previous to the desired point of ignition. As set out further below, the auxiliary fuel can be supplied by fuel pump H through lead L′ in such a way that at the beginning of injection nozzles N and N′ both eject fuel, but that at the desired point the supply of fuel through nozzle N′ ceases, all of the fuel going to nozzle N thereafter. Where the fuel is rather heavy a non-cooled sleeve 25 (Fig. 4) may be placed within retort K in order to facilitate by its accumulation of heat the evaporation of the retort fuel, such as shown in Fig. 4. In such case electric plug S which may be a sparking plug as an electrically heated wire may be used for starting only, hot point 26 being relied upon thereafter for ignition and the ignition may be timed by timing the injection of fuel through nozzle N′. Or a separate and distinct fuel pump may be used in order to supply a fixed amount of comparatively light fuel to nozzle N′. In fact, the structure and operation of the fuel pump hereafter described with its various adjustments, is the equivalent, in action, of two separately controllable pumps. The location of nozzle N′ may also be altered so as to give the best results.

Where gaseous fuel such as illuminating gas is obtainable a gas mixing valve may be substituted for carbureter M.

Where carbureter M and inlet valve 17 are used the lift of said valve and its period of opening may be decreased as above set forth so as to limit the amount of mixture being inhaled into retort K during the suction stroke of the engine, to such an extent that a substantial amount of burnt gases is allowed to remain within the retort. Thus their admixture with the new charge may be used to overcome any tendency of the retort mixture to detonate. In such case the quality of the carburetted mixture entering past the valve would be enriched correspondingly to supply the required amount of fuel. Or a smaller valve admitting fuel only could be substituted.

An explosive mixture in retort K could also be produced without the use of the crabureter or auxiliary nozzle N′ by starting injection through nozzle N at an earlier point in the compression stroke while compressed air is still rushing from the combustion chamber R into retort K, this inrushing air being relied upon to carry sufficient fuel spray into the retort to form an explosive fuel-air mixture therein. For this purpose passage 20 or 21 or both could be made smaller, which would have the effect, that a longer time period would be required until the pressures in space R and retort K are equalized and that particularly in high speed engines this point of equalization would occur later in the compression stroke. Thus the travel of air from the cylinder into retort K (which would be relied upon to carry fuel into the retort) could be maintained until the very point of ignition.

Detail description of pump shown in Figs. 6 and 7.

Shaft P carries gear 4 meshing with the half time gear as above described. It also carries double cam 30—31. The cams actuate cam followers 32 and 32′ oscillating around shaft 34 which is fixed at both ends in pump housing 35. The cam followers are held against the cams by spring-actuated plungers 36 and 37 which are guided by holes in projection 38 of housing 35 and by bushings 39 in the upper part of housing 35. Plunger 36 imparts the motion received from follower 32 to fuel plunger 40 sliding in hole 40′ in valve cage V. Plunger 37 imparts the motion received from follower 32′ to blade 41 oscillating around eccentric shaft 42 mounted in housing 35. The forward end of the blade slides freely in a slot 43 in plunger 37. Against this blade more or less half way between plunger 37 and shaft 42 rests plunger tappet 44 which imparts the motion received from blade 41 to fuel inlet valve 45 upon stem 46 sliding in hole 45′ in valve chest V.

It will be readily seen that by turning shaft 42 the fulcrum of its eccentric can be raised or lowered at will, thereby raising or lowering the position of tappet 44. As a further adjustment, adjusting screw 53 and locknut 54 are provided on tappet 44.

Valve 45 is held against its seat by spring 47. Plunger 40 is held by spring 48 against stop 49. This stop is loosely mounted on eccentric shaft 50 supported in housing 35, but is prevented from turning by adjustable stop 51, screwed into housing 35 and secured by locknut 52.

It will be readily seen that by turning shaft 50, the fulcrum of its eccentric can be raised or lowered at will, thereby raising or lowering stop 49 and thus limiting the outward stroke of plunger 40.

Above plunger 40 is mounted check valve 55 being connected by lead L to nozzle N. (See Fig 1.). Check valve 55′ being connected by lead L′ to nozzle N′ communicates with the plunger bore 40′ through small passage 56 which enters the plunger bore just above the top of the plunger when in its lowest position. Check valves 55 and 55′ may be of any standard design. The plunger bore 40′ also communicates with space 57 through passage 58. The upper portion of space 57 is closed off by plug 59, on which may be mounted a pet cock or relief valve. When valve 45 is held open, space 57 communicates past it through hole 45′ with longitudinal passage 60 connected to the main fuel supply 60^a.

61 and 62 are inspection plates. 63 is a baffle for the purpose of creating an oil pocket in the lower half of housing 35. The oil contained therein is picked up by gear 4 and splashed against the various parts inside of housing 35, thereby insuring ample lubrication.

The action of the pump is now as follows: Assuming the position shown in Fig. 6 as starting position, a further turning of shaft P in the direction of the arrow will bring the common face 64 of cams 30 and 31 in contact with faces 65 of followers 32 and 32′, causing them to rise along face 64 and raising up plungers 36 and 37 respectively. After taking up the clearance between the top of plunger 36 and the bottom of fuel plunger 40 (depending on the position of stop 49) plunger 36 will raise fuel plunger 40 driving the fluid imprisoned above it, (valve 45 being seated at the time), through check valves 55 and 55′ and after passage 56 has been overrun by the plunger, through check valve 55 only. At the same time plunger 37 will raise the end of blade 41, which in turn will raise tappet 44. Depending on the angular position of eccentric shaft 42, adjusting screw 53 will come sooner or later into contact with the bottom of valve 45 thereby raising it and opening the valve passage. The result will be that any fluid displaced thereafter by fuel plunger 40 will return past valve 45 into fuel supply line 60 rather than overcome the spring pressure of check valves 55 and 55′.

The eccentric shaft 42 is given such throw that at its highest position there is practically no clearance between screw 53 and the bottom of valve 45 and that valve 45 will thus be opened immediately after follower 32′ engages face 64 of the cam; while at its lowest position the clearance between screw 53 and the bottom of valve 45 will be considerable and valve 45 will not open until after follower 32 and plunger 40 have completed their stroke. (It will be noted that while face 64 of both cams coincide, cam 31 operating valve 45 has a higher total lift than cam 30 operating plunger 40.) It will be readily seen that by thus turning shaft 42, all or a portion of the stroke of plunger 44 can be made non-effective and that the injection of fuel can be terminated at will without however affecting the beginning of the injection or the rate thereof.

41′ shows the bottom position of blade 41.

In practice shaft 42 may be hand operated or may be connected to the governor of the engine.

It will also be noted that race 64 and faces 65 of followers 32 and 32′ are so designed as to maintain a uniform rate of raise of plungers 36 and 37, thus giving a uniform rate of fuel injection and avoiding wire drawing.

Upon further rotation of shaft P, faces 65 will leave face 64 of the cams and thereafter the followers 32 and 32′ will ride with their faces 66 on the contour of cams 30 and 31.

The contour of cam 30 returns soon thereafter in the form of a spiral to base circle 67 allowing follower 32 and plungers 36 and 40 to return to their bottom position; thus forming the suction stroke of plunger 40.

The contour of cam 31, however, is maintained at its maximum radius until after contour of cam 30 has returned to base circle 67. Thereafter contour of cam 31 likewise returns to base circle 67 in a smooth curve. Thus, regardless of the angular position of shaft 42, valve 45 will always be held open during the entire suction stroke of the fuel plunger and until plunger 40 has reached its bottom position.

It will also be noted that this design allows of a quick injection stroke (the injection stroke usually covering 40° of the crankshaft travel or 20° of the pump shaft travel); a slow suction stroke (thereby reducing the fluid friction through the inlet passages), and of a slow and smooth seating of valve 45.

By regulating stop 49 the point (time) of beginning of injection can be varied for both the main and auxiliary nozzles. By regulating shaft 42 the point (time) of the end of injection through the main nozzle may be varied. By regulating either of these controls the amount of full injection is controlled and varied; and by proper corresponding regulation of both the time of injection may be varied without varying the amount—without varying the period from start to finish of injection. Then, the proportionate amount of injection through the main and auxiliary nozzles may also be controllably varied by regulating stop 49, which regulates the distance the upper end of plunger 40 has to travel to cut off port 56. With a given disposition of port 56 and a given length of plunger 40, regulation of stop 49 automatically increases the proportion of fuel fed to the auxiliary nozzle just as the beginning of injection is advanced; and decreases the proportion as the injection beginning is retarded. But, by properly positioning port 56, or by making plunger 40 longer or shorter I get an independent control of the proportionate amount of fuel going to the main and auxiliary nozzles. This last may be done, for instance, by making the lower head 40^a of plunger 40 have a screw-threaded adjust-ability at 40^b to lengthen or shorten the plunger.

The pump shown here is for a one cylinder engine. A multi-cylinder pump can be readily produced by using housing 35, valve chest 46, and shafts P, 42 and 50, and fuel supply passage 60 in common for all pumps, but duplicating cams, cam followers, tappets, fuel plungers, fuel outlet valves, etc. for each pump. In such case adjustments 40^b, 51 and 53 can be used to adjust the fuel pumps with reference to the engine timing and to each other; while the adjustments at 42 and 50 adjust all the pump mechanisms in common. Such an arrangement is indicated for a two cylinder engine in Fig. 12.

The manifold is shown as applied to a 2 cylinder engine; in Fig. 1 a section thereof is shown. The exhaust enters the manifold from cylinder passages 22′ and is conducted through branches 70^a—70^a to the exhaust pipe 70. These pipes 70 may or may not be water-jacketed.

The inlet air being inhaled during the suction stroke of the engine enters funnel shaped chamber 71 through control grates 72 and 72′ and from there is conducted through passages 22 and past inlet valve 9 into the cylinder proper. Grates 72 and 72′ are fitted with a series of slots 73 and 73′ for the purpose of muffling the noise of the suction. Grate 72 is rigidly fastened to the manifold, while grate 72′ can be slid endways by the operator. Moving grate 72′ in one direction its slots will register with the slots in grate 72, and the air passage will be unobstructed. This is the running position of the motor. Moving grate 72′ in the other direction, the slots in grates 72 and 72′ will fail to register and the passage of air past them will be partially or entirely obstructed. This is the starting position of the motor.

Where two or more cylinders are used, preferably only one inlet pocket is provided for each two cylinders as shown thereby admitting the use of much larger grates and a more simple construction.

Figs. 1 and 2 show a special cylinder head with overhead valves and with an integral retort K.

Figs. 8 and 9 show a variation thereof with a separate retort. The latter can also be used for engines operating under the Otto cycle by applying thereto a standard type of manifold and carbureter connecting with inlet 22 and fitting a spark plug into the retort K.

Cylinder head F carries within it passages 22 and 22′ which at one end terminate into the valve seats of valves 9 and 9′ and at the other end register with suitable openings in manifold G. Manifold G is held to the cylinder head by vertical studs or bolts similar to the fastenings usually employed for holding the cylinder head to the cylinder. The valves are held against their seat by the action of springs 10 in the usual manner. They are operated by rockers 8 oscillating around shaft 11 which is supported from the cylinder head by uprights 12. The head is cooled by cooling water in spaces 23. The cooling water enters from jacket spaces 23^a of cylinder through holes 24 which register with similar holes in the cylinder head and leaves through opening 25 in the top of the head. It will be seen that pipes 22 and the valve seats are thoroughly cooled.

Valves 9 and 9′ are located to one side of the center line of the cylinder in order to allow nozzle passage 21 (in Fig. 1) or spark plug hole (in Fig. 8) to terminate at their lower end near the center of the cylinder, (the center of the cylinder head being commonly considered the most advantageous place for the location of the spark plug in the Otto cycle or the injection nozzle in the Diesel cycle).

In order to permit of the use of large valves, pockets 27 are provided in the upper part of cylinder E into which valves 9 and 9′ partly overhang. These pockets are such as to give a reasonably free passage of the gases past the valve seat. In case of breakage of the end of the valve stem (a frequent occurrence in practice), the valve by reason of its edge protruding into the pocket is prevented from dropping bodily into the cylinder and causing any damage therein.

The outlet openings of passages 22 and 22′ being in the same plane with the bottom of the cylinder head has the following advantages as contrasted with the usual method of attaching the manifold against the side of the cylinder head.

Simpler construction; only one surface has to be machined instead of two.

Easier alignment; in multi-cylinder engines using individual cylinders or cylinder heads, and using a side attached manifold, the cylinders, or the cylinder heads, must be aligned not only with respect to the base, but with respect to the manifold as well. While in this case alignment with the base is automatically, alignment with the manifold.

Readily removable cylinder heads; in multi-cylinder engines using separate cylinders or cylinder heads it frequently becomes necessary to remove one of them for inspection or repair. When using a side attached manifold, the whole manifold must be backed off, or removed entirely, before any one of the heads can be lifted without disturbing the manifold, the manifold being held in place by the remaining cylinder heads.

In Figs. 13, 14 and 15 I have shown a

preferred variational form of the fuel pump. The general arrangement and major features of action are the same here as in the form of pump before described; but there are certain amplifications of structure and certain other changes of structure that obtain a somewhat different action in detail. The shaft P carries a double cam 30—31 of approximately the same forms as heretofore described; and a follower 32 pivoted at 34 follows cam surface 30. The arm 41, pivoted on the eccentric shaft 42, has feet 43 that ride on cam surface 31; and the arm 41 also has a pin 41^b that overlies follower 32 so that arm 41 is always raised with follower 32 as that follower is raised by the action of cam surface 64 on follower surfaces 65 and 66. But cam surface 31, being longer in returning to the base circle as hereinbefore described, lets the arm 41 down more slowly than cam follower 32 comes down, keeping the inlet valve open as the pump plunger comes down. Follower 32 bears directly on plunger 36 as in the form previously explained, and this plunger pushes upwardly on the lower end of pump plunger 40 which is moved down by spring 48. The arrangement at 49, 50, is substantially the same as hereinbefore described, for the purpose of limiting the downward movement of pump plunger 40 and thus adjustably fixing the position from which it begins its upward stroke. In the head of block V the fuel discharge passages are here shown in different positions from what they are in Fig. 6. The passage 56^a that leads off laterally from pump cylinder 40′ here leads to the check valve 55 that controls fuel to line L; while a passage 56^b leads to check valve 55′ that controls passage of fuel to line L′ that goes to the retort nozzle. Passage 56^b is preferably concentric with cylinder bore 40′ and it has at its lower end a valve seat surface adapted to be closed by the small spring pressed valve 40^d mounted in the upper end of plunger 40. This valve is normally held in its uppermost position in plunger 40 by a small spring 40^h, its upward movement being limited by shoulder 40^g coming into contact with the lower surface of bushing 40^c. In Figs. 13 and 15, the plunger 40 is shown in its lifted position and the valve 40^d is shown in position shutting off the passage 56^b. The point in the upward movement of plunger 40 at which valve 40^d will close off passage 56^b may be regulated either by such a device as is shown at 40^b in Fig. 6; or by using valves 40^d of different lengths or by putting gaskets 40^f of different thicknesses under the body of check valve 55′.

The valve lifting arm 41 lifts on rod 44 that in turn lifts on valve stem 46^a, rod 44 being effectively adjustable in length by means of the nuts 53 and 54. This valve stem 46^a, playing in the bore 45′, has a reduced upper end as at 46 carrying the inlet valve 45 that seats on valve seat 45^a. The inlet port 58 that leads from valve 45 to cylinder bore 40′ is here shown communicating with valve bore 45 below valve 45 instead of above it as in Fig. 6; and the port 60 that leads fuel to valve 45 from the fuel pipe connection 60^a is shown coming in above valve 45. Valve 45 is normally held down on its seat by spring 47^a above it, and a removable housing 59^a above the spring and valve allows access to the valve. With port 58 located beneath valve 45, the pressure raised on the fuel by the action of the pump does not tend to hold the valve down. This pressure, in the form now under discussion, exerts a downward pressure at the shoulder 46^b on valve stem 46^a and also a substantially equal pressure upwardly on that part of valve 45 that is within seat 45^a. The pressures being balanced, there is no extra pressure against which the valve lifting arm 41 has to act and the wear on the cams is thus reduced. If desired, the bore 45′ may be somewhat increased in size at 45^b directly under the valve seat 45^a, (see Fig. 15) thus to make the fluid pressure upward on the valve a little greater than the pressure downward on the shoulder 46^b. This excess of fluid pressure upward is not normally sufficient to raise the valve against the downward pressure of spring 47^a; but in case an excessive pressure is raised by the pump, due to clogging etc., the valve then acts as a safety valve to allow the excess pressure to redischarge back into the fuel line.

In operation, arm 41 will always move upwardly when cam follower 32 moves upwardly acted upon by cam surface 64. Thus, the plunger 40 and the valve stem will be raised by one and the same action; but the time at which the valve stem is raised will depend upon the adjustment of eccentric 42. This eccentric has a range of adjustment sufficient to raise and open valve 45 early enough for the least fuel supply—that is, to effect such an early opening of the valve during the pumping stroke of the plunger as to allow practically all, or even all, the fuel to return to the fuel supply pipe. In fact, the range of adjustment is such that valve 45 can be permanently held off its seat. On the other hand the range of adjustment by eccentric 42 is such that valve 45 does not open until plunger 40 has covered almost all its stroke—say about ¾ of its up-stroke. But it always opens before the completion of the pump plunger stroke. This arrangement insures at all times a sufficient opening of valve 45 to allow free passage of liquid back to the supply pipe and relieves the pressure of the cam follower on the cam at the point where face 64 and contour 31 meet, thereby reducing wear at that point of the cam that is most liable to wear.

In general, it will be seen that less work is imposed on the governing mechanism—the mechanism that lifts valve 45 during the up-stroke of pump plunger 40; and the result is better and more accurate governing action. It will also be noted that the valve seat or valve 45 is at the highest point in the liquid pressure system, and thus any air that may have entered the pump will collect there and will be blown out whenever the valve opens at the end of the injection stroke; and thus the pump is self priming.

The double injection system lends itself to a variety of fuel controls.

Thus the description that I have given so far has presumed that the springs, such as shown at 55^a and 55^b in Fig. 15, of check valves 55 and 55′ are of about equal strength; and being thus of about equal strength the fluid flow will be divided more or less equally between lines L and L′ up to the time that port 56 is covered by the plunger in the form shown in Fig. 6 or up to the time that valve 40^d seats in the form shown in Fig. 13. This arrangement provides for the injection of a certain amount of fuel into the combustion chamber through line L at the same time that fuel is being injected into the retort through line L′, and then provides for additional injection of fuel into the combustion chamber after combustion has commenced. In this way there occurs in the combustion chamber a certain amount of initial combustion at constant volume and then thereafter a combustion of the balance of the fuel at constant pressure.

But it may be desirable to eliminate the constant volume combustion either partially or entirely; and this can be done by placing a comparatively heavy spring in check valve 55 and a comparatively light spring in check valve 55′. The heavy spring is strong enough that check valve 55 will not open until after port 56 has been cut off in Fig. 6 or valve 40^d has seated in Fig. 13; the entire amount of fuel up to that time going to the retort. Then after the retort has been cut off, the entire fuel displacement of the pump will go to the cylinder to be burned at constant pressure.

Or, it may be desirable in small high speed engines, where the time allowed for evaporation of the fuel supply is rather limited, and where the burning of a substantial part of the fuel is desired to be at constant volume, to change the arrangement so that line L′ will connect with the main fuel nozzle into the combustion chamber and the line L with the nozzle injecting into the retort. In that case, using again a comparatively stiff spring in check valve 55, the fuel will first be injected into the compression and combustion space and allowed to vaporize and form an explosive mixture therein, previous to the injection of any fuel into the retort and previous to ignition resulting from injection of fuel into the retort. In this case the injection of fuel into the retort governs the time of ignition and the injection of the main fuel into the combustion space governs the strength of the explosion. In this particular case, like in the others, the amount of retort fuel can be maintained constant and the amount of the main fuel can be altered by altering the point of beginning of the fuel pumping by manipulation of eccentric shaft 50.

I have fully described how the pump mechanism, in either of its forms, can be adjusted to change the absolute amounts of fuel going either to the retort or to the combustion chamber, and also to change the proportion between these two amounts. In practice, it is of course, desirable, once the proper and effective amount of retort fuel is ascertained, to keep that amount of fuel constant or practically constant regardless of the output of the engine and to vary the combustion chamber injection in accordance with the required output. It needs no further explanation to show that the mechanisms I have here explained are perfectly capable of achieving this result. It is one of the excellencies of this arrangement that, regardless of the amount of combustion in the work cylinder proper, the amount of combustion in the retort is practically constant, variation in the amount of combustion in the combustion chamber having only a small secondary effect on the amount of combustion and heat developed in the retort. Therefore, the retort can be kept at practically constant temperature. The slight secondary effect of the combustion heat can be readily counterbalanced by slightly decreasing the amount of retort fuel at full load and slightly increasing it at light load, as has been shown in the description of the pump mechanism. This arrangement of two injection nozzles and controlling means to control the amount of fuel to those nozzles, overcomes one of the greatest difficulties experienced with engines that use one large retort pump and one nozzle; for in such engines on full load the retort tends to overheat, and causes preignition, while at light loads the retort tends to cool off to such an extent as to cause misfiring.

In Fig. 16 I have shown a preferred form of cylinder head variation, somewhat similar to that shown in Fig. 8, but using two nozzles like the form shown in Fig. 1. Here the retort K is shaped semi-spherically to hold a small spherical bulb K^1 that has an opening 20^a in its lower side registering with passage 20 that leads to main nozzle passage 21. (The effective part of the bulb K^1

BEST

is its upper half as it is here the fuel strikes; and the lower half—the semi-spherical skirt—may be omitted if desired.) Spark plug S is located in the top of the hot wall K^1; and the retort injection nozzle N′ is arranged, as shown in the drawings, so that its line of injection will not directly strike the spark plug but so that a sufficient amount of spray will hit it to cause sure ignition. Of course, it will be understood that here, as in the other forms described, ignition by contact of the fuel with the hot wall of the bulb K^1 may be relied upon, with or without the spark plug S. Also fuel nozzle N′ is slightly offset sideways so as not to interfere with the main fuel nozzle N′ which is located central with passage 21.

Both Figures 8 and 16 show the decidedly cupshaped piston with a separating wall 82 to keep the head at a fairly high and fairly constant temperature in order to promote rapid evaporation of the fuel, without, however, reaching so high a temperature as to cause auto-ignition. They show the conical passage 21 inclined to just an extent that in combination with the curvature of the piston top it will cause a uniform distribution of the fuel throughout the compression space. They also show the passage 20 so located that the flame from the retort will hit the lower side of channel 21 and ignite any drippings from nozzle N, and thus avoid any accumulation of unburnt fuel due to temporary poor condition of the nozzle, etc.

Having described a preferred form of my invention, I claim:

1. A fuel pump for an internal combustion engine, comprising a cylinder having two spaced apart outlet ports, a plunger in the cylinder and adapted to be moved to position to close one of said ports, means to controllably vary the total effective pumping stroke of the plunger, and means independent of the first means to controllably vary the proportion of such stroke necessary to close said one port.

2. A fuel pump for an internal combustion engine, comprising a cylinder having two spaced apart outlet ports, a plunger in the cylinder normally uncovering both of said ports, and means to give the plunger a variable stroke in the cylinder to cover one of said ports, said means comprising an operating mechanism having a constant stroke and adapted to push against the end of the plunger, and a controllable variable stop to limit movement of the plunger toward said mechanism.

3. A fuel pump for an internal combustion engine, comprising a cylinder having two spaced apart outlet ports, a plunger in the cylinder normally uncovering both of said ports, means to give the plunger a variable stroke in the cylinder to cover one of said ports, a relief valve in communication with the cylinder, and controllably variable means actuated in conjunction with the plunger stroke imparting means to open the relief valve.

4. A fuel pump for an internal combustion engine, comprising a cylinder having two spaced apart outlet ports, a plunger in the cylinder normally uncovering both of said ports, means to give the plunger a variable stroke in the cylinder to cover one of said ports, said means comprising an operating mechanism having a constant stroke and adapted to push against the end of the plunger and a controllable variable stop to limit movement of the plunger toward said mechanism, a relief valve in communication with the cylinder, and a controllably variable means actuated in conjunction with the plunger stroke imparting means to open the relief valve.

5. A fuel pump for an internal combustion engine, comprising a cylinder with an outlet port, a pump plunger in the cylinder, a cam shaft and a cam thereon to actuate the pump plunger through a constant stroke, a controllably variable stop to limit movement of the pump plunger toward the actuating cam, a relief valve in communication with the cylinder, a valve actuating cam on the cam shaft, a member actuated by the valve actuating cam and adapted to push upon the valve, and means to vary the effective length of said member so that it will strike and begin to move the valve at a controllably variable time.

6. A fuel pump for an internal combustion engine, comprising a cylinder having spaced apart outlet ports, an inlet and relief port communicating with the cylinder, a plunger in the cylinder, a spring urging the plunger outwardly, a variable stop against which the plunger rests and by which its outward stroke is limited, a cam shaft with cam thereon adapted to impart an inward movement to the plunger, an inlet and relief valve controlling the inlet and relief port, such valve being mounted on a stem and adapted to be opened by inward movement, a spring tending to normally seat the valve, a valve actuating cam on the cam shaft, a member actuated by the valve actuating cam and adapted to push upon the valve, and means to controllably vary the normal position of said member with reference to the valve so as to vary the time during its movement at which it strikes the valve.

7. A fuel pump for an internal combustion engine, comprising a cylinder with spaced apart outlet ports, an inlet and relief port communicating with the cylinder, a plunger in the cylinder, a spring urging the plunger outwardly, a variable stop against which the plunger rests and by which its outward stroke is limited, a cam shaft with cam thereon adapted to impart through a con-

stant stroke an inward movement to the plunger, an inlet and relief valve controlling the inlet and relief port, such valve being mounted on a stem and adapted to be opened by inward movement, a spring tending to normally seat the valve, a valve actuating cam on the cam shaft, a member actuated through a substantially constant stroke by the valve actuating cam and adapted to push upon the valve, and means to controllably vary the normal position of said member with reference to the valve so as to vary the time during its movement at which it strikes the valve, the plunger actuating cam being shaped to impart an inward movement to the plunger and then allow its outward movement immediately thereafter, and the valve actuating cam being shaped to lift the valve and then hold the valve lifted during the whole of the outward movement of the pump plunger.

8. The combination as specified in claim 6, and means to adjust the normal relation between the plunger and one of said outlet ports adapted to be closed by the plunger.

9. In a fuel pump for a multi-cylinder engine, a pump mechanism for each engine cylinder embodying a pump cylinder and a plunger, common actuating means for all the plungers, means common to all the plungers for controllably varying in unison their points of start of pumping stroke, means individual to each plunger to control its point of start of pumping stroke independently of the other plungers, controllably variable means common to all the plungers to vary the point of end of their effective pumping strokes, and means individual to each plunger for doing the same independently of the others.

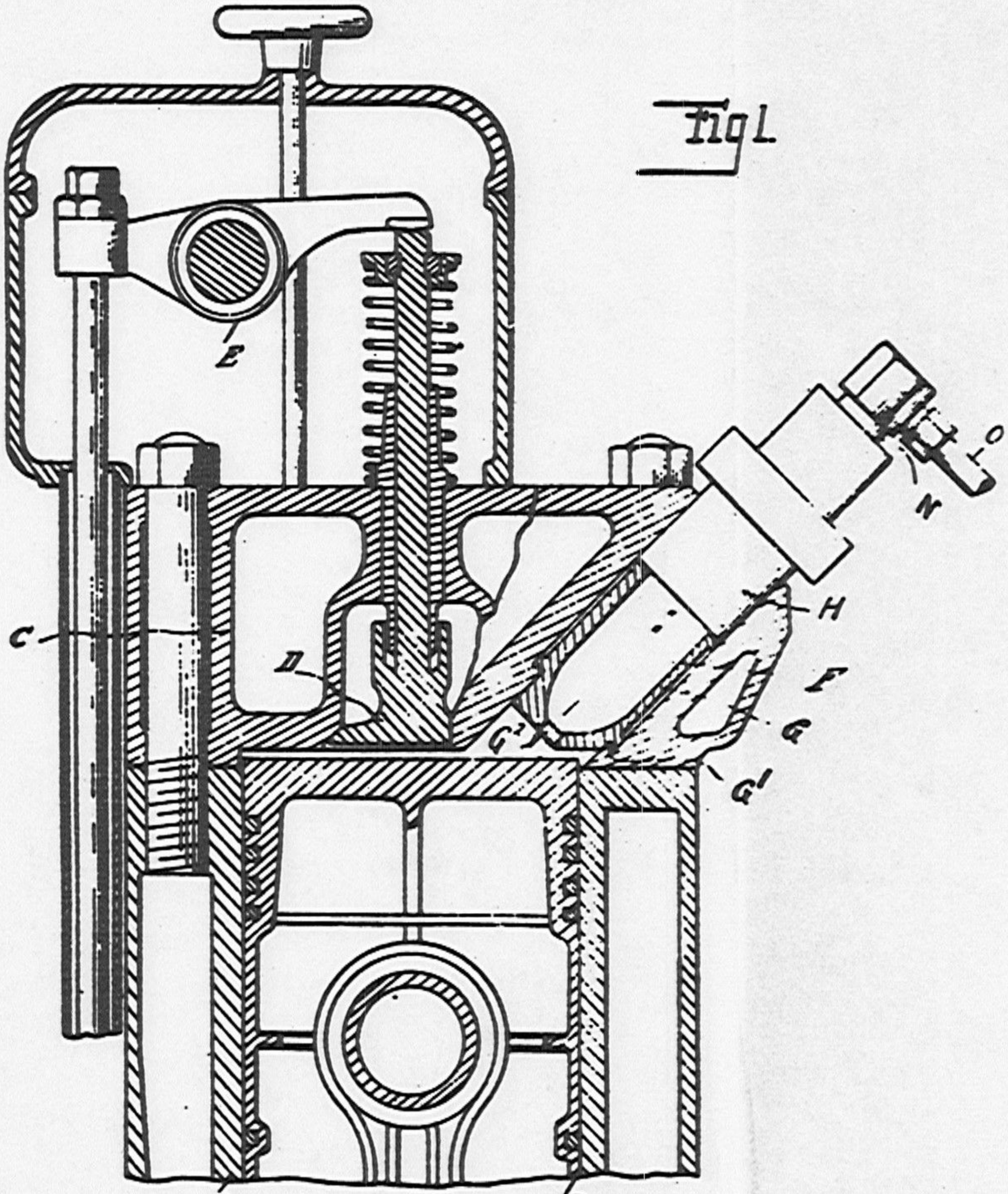
10. In a fuel pump for a multi-cylinder engine, a pump mechanism for each engine cylinder embodying a pump cylinder with plunger and relief valve, common actuating means for all of the plungers, common actuating means for all of the relief valves, an arrangement whereby the relief valves can be opened at variable points to terminate the pumping strokes of the plungers, means common to all of the plungers for controllably varying the effective pumping stroke, and means individual to each plunger to vary its effective pumping stroke independently of the other plungers.

In witness that I claim the foregoing I have hereunto subscribed my name this 14th day of February 1923.

OSCAR WERNER.

[This Drawing is a reproduction of the Original on a reduced scale]

Fig 1.



2 SHEETS
SHEET 2

Fig.2.

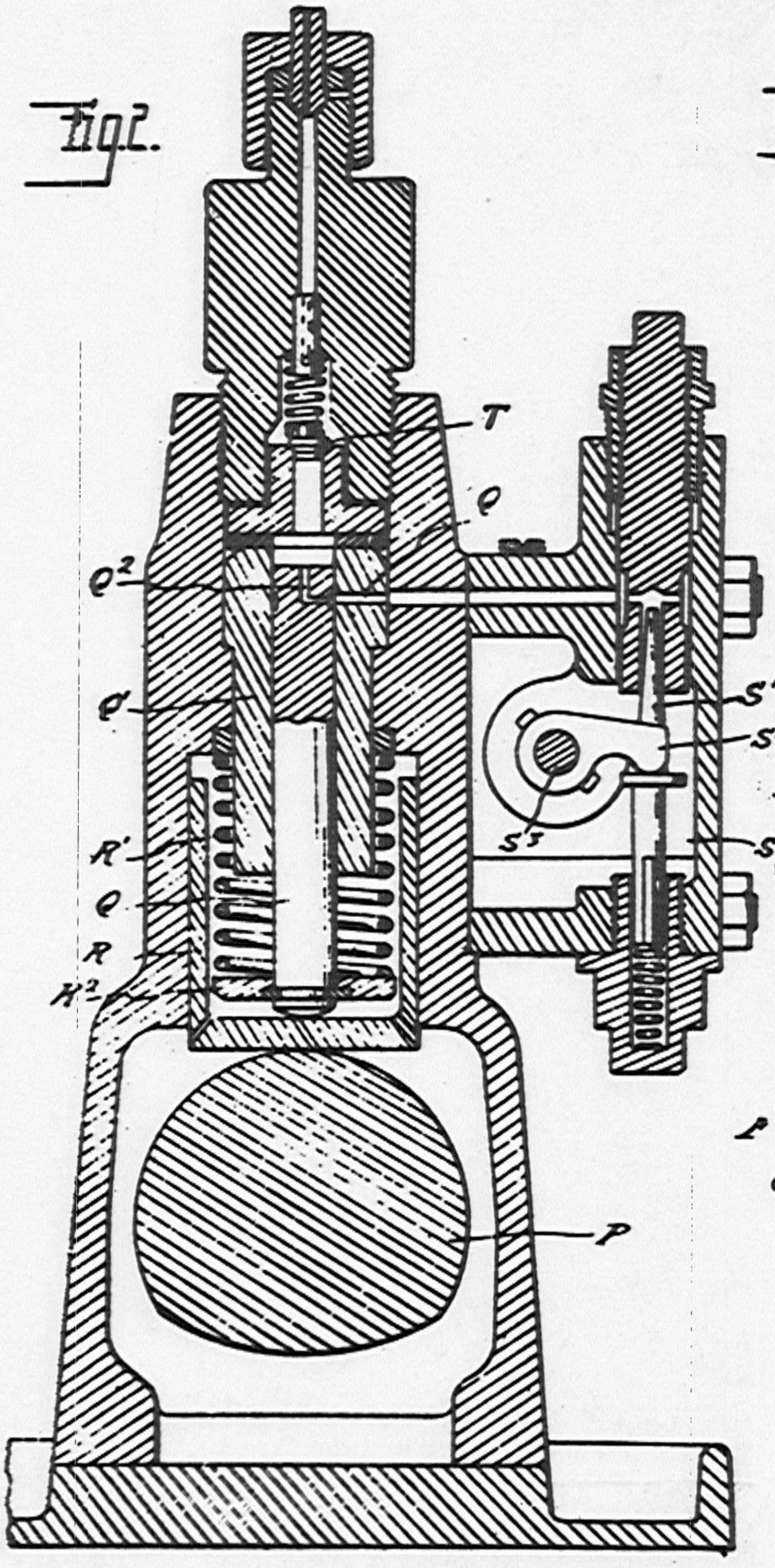
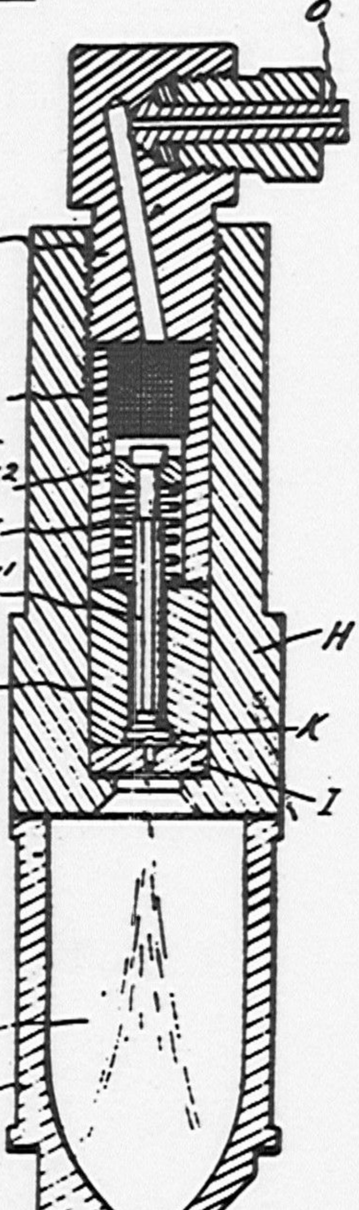


Fig.3.



Charles & Read Ltd. Photo Litho.

PATENT SPECIFICATION

Convention Date (United States): Feb. 27, 1930. **373,647**

Application Date (in United Kingdom): Feb. 16, 1931. No. 4905/31.

Complete Accepted: May 17, 1932.

COMPLETE SPECIFICATION.

Improvements in the Liquid Fuel Injection Arrangements and Combustion Chambers of Oil Engines.

We, **Hill Diesel Engine Company**, a corporation organized under the laws of the State of Michigan, one of the United States of America. of 238, Mill Street, City of Lansing, County of Ingham, State of Michigan, United States of America, Manufacturers, Assignees of **Harry Ueaver Hill**, a citizen of the United States of America, of 238, Mill Street, City of Lansing, County of Ingham, State of Michigan, United States of America, Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to internal combustion engines of the Diesel or semi-Diesel type in which there is employed an auxiliary cylindrical ante-chamber disposed in oblique relation with respect to the axis of the cylinder and connected through a restricted passage with the working cylinder and in which ante-chamber a portion of the fuel and air mixture is ignited before the combustion proper takes place in the working cylinder.

An object of the present invention is to effect a mixture of fuel and air only in the lower portion of the ante-chamber while the air in the upper portion is retained in an unmixed condition to aid the subsequent complete combustion in the engine cylinder when it is forced thereinto by the pressure produced by the combustion in the lower portion of the ante-chamber.

It is also an object of the present invention to provide a thorough mixing and turbulence of the fuel injected directly through the ante-chamber with the air in the combustion chamber and also to provide complete combustion through a thorough mixture of the unmixed air from the ante-chamber with the burning mixture within the combustion chamber.

With these objects in view according to the invention the fuel injection nozzle at the outer end of the cylindrical ante-chamber and a restricted passage connecting said ante-chamber with the clearance space of the engine cylinder are disposed in the direction of the axis of the fuel jet being laid preferably on the longitudinal axis of said ante-chamber which is disposed in oblique relation to the cylinder axis and fuel is injected with sufficient force so as to penetrate without commingling with the air in the outer portion of said ante-chamber and to commingle with and be ignited by the compressed air adjacent to the opening between said ante-chamber and cylinder whereby the heat of combustion communicated to the unimpregnated air in said ante-chamber will force the burning mixture inward and supply additional oxygen for completing combustion.

In order that the invention may be clearly understood and readily carried into effect the same will now be described more fully with reference to the accompanying drawings in which:

Figure 1 is a central longitudinal section through a portion of an engine of my improved construction;

Figure 2 is a section of the fuel pump;

Figure 3 is a section through the fuel nozzle and ante-chamber.

A is the engine cylinder, B the piston, C is the cylinder head and D one or more valves in the head depending upon whether there is a single passage or separate passages for inlet and exhaust. E is a suitable valve operating mechanism.

Connected with the compression space of the cylinder is an ante-chamber F preferably obliquely inclined and arranged so as to avoid interference with the valve or valves. This ante-chamber may be formed in the main casting of the engine head but is provided with a liner G seated upon a shoulder G^1 and tapered at its inner end to form a restricted orifice G^2 communicating with the cylinder. The volume of the ante-chamber is preferably substantially equal to the clearance volume of the combustion space in the engine cylinder and the diameter of the orifice is preferably substantially one-fourth that of the ante-chamber. The length of the ante-chamber is approximately twice its diameter. The liner G has its outer surface reduced in diameter over the greater portion of its length to

[Price 1/-]

reduce contact with the cold walls of the cylinder and thereby to retard the transfer of heat.

The fuel nozzle is arranged at the outer end of the ante-chamber so as to discharge axially thereinto. This nozzle may be of any suitable construction but as shown comprises a casing H fitting within the chamber in the head which receives the liner G and bearing against the outer end of said liner. Within this casing is a disk I having a spray aperture of the desired area and adjacent to this disk is a bushing J having a seat for a valve K. The stem K^1 of the valve extends through the bushing and is provided with a collar K^2 for engaging the valve spring L which holds the valve normally closed. A filter M is arranged on the outside of the valve and the fuel is supplied through an apertured fitting N from the supply conduit O.

The pump for supplying the fuel is actuated from a cam shaft P preferably driven at engine shaft speed by mechanism not shown. This pump comprises a plunger Q in a pump barrel Q^1 and as shown as actuated through the medium of a cylindrical cam follower R recessed to receive the spring R^1 that bears against a collar R^2 on the lower end of the plunger. Fuel is supplied to the pumping barrel from a fuel chest S which is kept normally full of fuel by a gravity feed or by a low pressure pump (not shown). The supply of fuel from the chest to the barrel may be regulated by a metering pin S^1 which is actuated by a rock arm S^2 from a rock shaft S^3 operated either manually or by an automatic governor (not shown). The fuel passing the metering pin and entering the barrel will be ejected by the plunger past a check valve T and into the conduit O from which it is forced through the filter M and past the valve K to the jet orifice in the disk I. At the completion of the stroke of the plunger Q a relief port Q^2 registering with the inlet port Q^3 will relieve the pressure on the fuel in the conduit O and permit the quick seating of the valve K.

With the construction as described, the air which is admitted to the cylinder through the valve D will upon the compression stroke be forced through the orifice G^2 into the ante-chamber F and will be raised to the desired pressure. The fuel which is ejected through the orifice in the disk I will form a concentrated jet directed through the axis of the ante-chamber towards the opening G^2. When the engine is started from the cold the viscosity and density of the liquid fuel is such that the spray will carry completely through the ante-chamber of the orifice G^2 into the clearance space of the engine cylinder. This will cause the engine to start without any special starting apparatus or the use of any special fuel. As soon, however, as the parts are warmed up the fuel spray instead of carrying completely into the engine cylinder will meet the compressed air passing inward through the port G^2 commingling therewith and being automatically ignited by the heat of compression. The fuel injection is timed to occur near the completion of the compression stroke of the engine and the heat generated by initial combustion is transmitted to the unimpregnated air in the upper part of the ante-chamber causing it to expand and force the rich mixture at the bottom and near the opening out into the cylinder space and with such force as to cause great turbulence and complete mixing with the air in the cylinder. At the end of a period of temperature pressure rise the unimpregnated air in the upper part of the ante-chamber has expanded and ejected practically all of the impregnated air from said chamber and further expansion of the unimpregnated air due to the outward movement of the engine piston supplies air to the combustion still in progress in the engine cylinder. This insures very complete combustion of all the fuel and avoids the formation of objectionable deposits.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. An internal combustion engine of the type referred to, wherein the fuel injection nozzle at the outer end of the cylindrical ante-chamber and a restricted passage connecting said ante-chamber with the clearance space of the engine cylinder are disposed in the direction of the axis of the fuel jet, being laid preferably on the longitudinal axis of said ante-chamber which is disposed in oblique relation to the cylinder axis, and fuel is injected with sufficient force so as to penetrate without commingling with the air in the outer portion of said ante-chamber and to commingle with and be ignited by the compressed air adjacent to the opening between said ante-chamber and cylinder whereby the heat of combustion communicated to the unimpregnated air in said ante-chamber will force the burning mixture inward and supply additional oxygen for completing combustion.

2. An internal combustion engine of the type referred to having its parts con-

structed, arranged and adapted substantially as herein described with reference to the accompanying drawings.

Dated the 16th day of February, 1931.

HASELTINE, LAKE & Co.,
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Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1932.

Filed May 4 1950 Harry M. Hull, Clerk

Plaintiff's Exhibit No. 1

DEPARTMENT OF COMMERCE
United States Patent Office

* * * *

Pending Application of
Neil O. Broderson,
Filed May 13, 1942, Serial Number 442,830,
for
Improvement in Method of Operating Internal
Combustion Engines.

* * * *

PETITION FOR UNITED STATES LETTERS PATENT

(Sole Inventor)

To the Commissioner of Patents:

Your petitioner *NEIL O. BRODERSON*, a citizen of *the United States*, residing at *Rochester*, in the County of *Monroe*, and State of *New York*, P. O. Address *c/o Rochester Button Company, Rochester, New York*, prays that Letters Patent may be granted to him for improvements in *METHOD OF OPERATING INTERNAL COMBUSTION ENGINES* set forth in the annexed specification. He hereby appoints

PIERCE & SCHEFFLER
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a firm consisting of JAMES F. PIERCE, RICHARD L. SCHEFFLER, RALPH E. PARKER, and HAROLD T. STOWELL, Register No. 8562, his attorneys with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to sign his name to the drawings, to receive the Letters Patent, and to transact all business in the United States Patent Office connected therewith.

Signed at *Washington, District of Columbia,* this *7th* day of *May* 1942.

/s/ Neil O. Broderson

SPECIFICATION

To All Whom It May Concern:

BE IT KNOWN That I, *NEIL O. BRODERSON,* a citizen of *the United States,* residing at *Rochester* in the County of *Monroe,* and State of *New York,* have invented certain new and useful improvements in *METHOD OF OPERATING INTERNAL COMBUSTION ENGINES* of which the following is a specification:

This invention relates to a method of operating internal combustion engines, particularly four-cycle internal combustion engines.

The conventional four-cycle induction internal combustion engine in its present state of development has several serious defects. Particularly important among these is the relative inefficiency of such engines. Maximum efficiency is obtained only over a narrow range of power output, which range is usually located near the maximum power output of the engine. This is due, in part, to the fact that in a given engine using a particular fuel there is a certain optimum ratio of fuel to air in the mixture which will ignite and burn evenly without detonation to deliver a smooth flow of power to the piston. This ratio may be varied somewhat without seriously reducing efficiency, but the limits of variation are much narrower than the range of power output required to be delivered by the engine. The displacement of the engine, the compression ratio, and maximum usable fuel to air ratio are factors determining the upper limit of power output of the engine. At lower than maximum power demand, the amount of fuel fed must be reduced, but this reduction can be continued only to a limited extent before the mixture becomes too lean properly to operate the engine. Before this point is reached, conventional induction engines provide for throttling the air taken into the combustion chamber as the amount of fuel fed is reduced in order to maintain the fuel to air ratio within ignitable and operable limits. Throttling, by decreasing the volume of air in the cylinder, reduces the efficiency of conversion of the heat energy from the combustion of fuel into useful work, and, furthermore, at low power demands, more fuel per unit of air must be added to the combustion chamber than corresponds to the lowered demand in order to keep the fuel to air ratio within ignitable limits, thus resulting in a waste of fuel and a loss in efficiency.

In my method of operating an internal combustion engine, air is drawn into the combustion space substantially unthrottled under all conditions of operation. Notable advantages ensue; namely, a uniform compression ratio is provided at all degrees of power output. This is especially advantageous at low power output where a higher than usual compression ratio may be utilized in conjunction with segregation of the fuel adjacent the locus of ignition at the time of ignition and the provision of a body of substantially pure air under compression in other parts of the combustion space remote from the locus of ignition. More efficient utilization of the combustion energy of the fuel is thereby obtained, because the substantially pure air readily absorbs and transmits to the piston the energy liberated by combustion of the fuel. This energy is used to do work and is not dissipated as heat through the walls of the cylinder.

Another defect of the conventional induction internal combustion engine is that the modern engine operating under a high compression ratio must use specially prepared or treated fuel if detonation is to be largely avoided. Even when such fuels are used, detonation occurs under some conditions of operation. Detonation has been explained as being due to the exploding of the fuel-air mixture in the unburned mixture preceding the flame. A flame front radiates outwardly from the point of ignition which compresses and heats the mixture in advance of it until a point is reached where the remaining unburned mixture attains a state of high compression and high temperature sufficient to cause it to explode. This explosion is commonly referred to as "knock", and when an engine "knocks" the efficiency, power output, smoothness and quietness of operation are deleteriously affected.

An object of this invention is to provide a method of operating a four-cycle internal combustion engine so that higher overall efficiency is attained at all speeds and degrees of power output of which the engine is capable with a given fuel.

Another object of the invention is to provide a method of operating such an engine whereby substantially to reduce the tendency to detonate under all conditions of engine output, and thereby to achieve quiet, smooth and efficient operation of the engine.

Another object of the invention is to provide a method of operating an internal combustion engine of the type specified using low grade fuel without loss of efficiency while avoiding objectionable detonation. High test fuels and those containing "anti-knock" preparations can be used at higher compression than the present limit by means of the method of the invention, for the principle under which it is operated obviates knock.

Further objects and advantages of the invention will be in part apparent and in part pointed out in the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a sectional view, taken along the line 1-1 of Fig. 2 looking in the direction of the arrows, of one form of combustion chamber and associated parts of an internal combustion engine adapted to be operated in accordance with the principles of this invention;

Fig. 2 is a sectional view of the apparatus shown in Fig. 1 taken along the line 2-2 of the latter figure;

Fig. 3 is a graph of the operation of a four-cycle engine in accordance with the invention;

Fig. 4 is a sectional view of a combustion chamber and associated parts adapted to be operated in a further embodiment of the principles of the invention;

Fig. 5 is a graph showing the relation of fuel fed to piston position in a typical illustrative embodiment of the invention, and

Fig. 6 is a graph illustrating the method of the invention and showing particularly how detonation is suppressed.

The method of operating an internal combustion engine according to this invention comprises admitting air to the combustion chamber of the engine and compressing the air within the combustion chamber, injecting into an auxiliary combustion zone communicating with and forming part of the combustion chamber controlled charges of fuel increasing in amount with increasing power demand upon the engine during a controlled period of time comprised between the beginning of induction and the completion of compression, effecting a differential distribution of the fuel between the auxiliary combustion zone and the remaining portion of the combustion chamber to provide in said auxiliary combustion zone an ignitable fuel mixture at the time of ignition under all conditions of power demand, and igniting the mixture under compression in the auxiliary combustion zone.

More particularly, the method of the invention comprises admitting substantially constant charges of air to the combustion chamber of a four-cycle internal combustion engine, at least a part of the air preferably being admitted through an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston and preferably from 10% to 50% of the volume of the total combustion space at top center position of the piston, compressing the air within the combustion chambers, supplying to said combustion chambers controlled charges of fuel increasing in amount with increased power demand upon the engine, at least a portion of the fuel being injected into the auxiliary combustion chamber during the compression stroke in amount varied with respect to the total quantity of fuel supplied to effect a controlled stratification of the total fuel supply between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in the composition of the fuel-air mixture obtained in the main combustion chamber. Advantageously the distribution of the fuel betwen the auxiliary and main combustion chambers is controlled to provide a fuel-air composition in the main combustion chamber which is outside the range of detonating compositions under all conditions of power demand.

The fraction of the fuel which is injected into the auxiliary combustion chamber during the compression stroke is related to the relative sizes of the auxiliary and main combustion chambers, to the power demand on the engine, and to the composition range of ignitable mixtures of the fuel in use, by the formula

$$X=\frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke; V is the number of unit weights of air contained in the total combustion space at top center position of the piston (that is, V is the total volume of the combustion space expressed in unit weights of air); A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber (A is preferably not substantially outside the range 0.1 to

0.5); F is the unit weights of fuel supply per charge at full load; B is the amount of the load expressed as a fraction of the fuel supply at full load (thus BF is the unit weights of fuel per charge at any fraction of full load); C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as a fraction of the mixture of air and fuel. C will vary with the particular fuel used and for any particular fuel can be selected from a definite range of values. Advantageously C is so selected as to provide a non-detonating fuel mixture in at least the main combustion chamber.

In the operation of an internal combustion engine in accordance with the invention, the total fuel supply may be injected into the auxiliary combustion chamber, the duration and timing of the injection being varied with respect to the intake and compression strokes in accordance with the principles set forth above, or the portion of the fuel supplied during the intake stroke may be mixed with the intake air before it is supplied to the combustion chamber, only that portion of the fuel supplied during the compression stroke being injected into the auxiliary combustion chamber. The latter method of operation is particularly advantageous when part of the air is admitted directly into the main combustion chamber, and this method of operation is essential when all of the air is admitted directly into the main combustion chamber.

In Fig. 1, 1 represents the walls providing a cylinder accommodating the reciprocating piston 2 of a four-cycle internal combustion engine. The reference numeral 3 indicates an offset wall providing, together with the cylinder head 4, an auxiliary combustion zone 5. The main combustion zone 6 overlies the piston 2. An intake valve 7 is provided for the admission of air or a mixture of air and fuel during the induction stroke of the piston, and this valve is timed to operate as is conventional in four-cycle engines. Exhaust valve 8 is positioned in the cylinder head over the piston and it also operates conventionally to permit egress of the products of combustion on the exhaust stroke. An ignitor 9 is located in side wall 3 and extends into the auxiliary combustion chamber for the purpose of igniting the fuel-air mixture therein at or near top dead center of the piston between the compression stroke and the power stroke. The timing of the firing is adjusted in the conventional manner. A fuel injector 10 also enters wall 3 for injecting or spraying fuel or a rich mixture of fuel and air into the auxiliary combustion zone 5. A fuel pump (not shown) supplies metered and variable quantities of fuel and injects the same periodically through the nozzle into the auxiliary combustion zone. The quantity of fuel injected and the period of injection are controllable variables as will be more fully explained hereinafter.

In operation, air or a mixture of air and fuel is drawn into the combustion space on the induction stroke through intake valve 7. Preferably this air is not throttled for low power operation, but is drawn in unthrottled for all conditions of operation.

At least a portion of the fuel employed is injected into the auxiliary combustion zone 5 by nozzle 10. An important feature of this invention is the timing of the period of injection of the fuel and the quantity of fuel injected in accordance with the power demand upon the engine.

The fuel injector need not be positioned as shown so long as it is positioned to inject fuel into the auxiliary combustion zone. For example, it may be placed at the necked-down juncture of the main combustion zone and the auxiliary combustion zone or it may be situated in the side wall of the main combustion zone and directed at the auxiliary combustion zone across the main combustion zone.

Fig. 3 shows in graph form how the operation of a four-cycle engine in accordance with the invention is carried out. The curve is sinusoidal and represents the position of the piston with respect to the flywheel. The time of ignition and the various periods of fuel injection are indicated on the curve.

At low power demand, as when the engine is idling, very little fuel is required. Under these conditions, all the fuel may be injected into the auxiliary combustion chamber during the compression stroke. For example, fuel injection may be started at some point I and stopped at some Point I'. Substantially all the fuel so injected remains in the auxiliary combustion zone due to the inrush of air from the main combustion zone. The quantity of fuel injected is regulated so that a readily combustible mixture is adjacent the locus of ignition at the time of ignition. The main combustion chamber contains substantially only air. By this method of operating, it is possible to have an ignitable combustible mixture at the firing point when the spark is made, which mixture is sufficient to keep the engine idling, while the entire fuel charge is considerably less than would be required were the fuel mixed with the air prior to its induction into the cylinder.

The mean period of injection of fuel may be defined as the point in the cycle when half the fuel has been injcted into the combustion zone. With respect to the fuel injected between I and I', this may be represented by a point M in Fig. 3. As the engine is called upon to deliver increasing power to a maximum, the mean period of fuel injection is advanced. This may be accomplished by advancing the time when injection is started while keeping fixed the rate of injection and the time when injection is stopped, thereby increasing concomitantly the amount of fuel injected. Or, the mean period of fuel injection may be advanced together with an increase in the amount of fuel injected in any convenient way.

The period of fuel injection may be advanced until the point of first injection reaches a point II on the curve which is located about 20% of the way down the intake stroke. This point may be reached under full load operating conditions. Preferably under all conditions of opertion the injection is not stopped until after the compression stroke has begun, although with some engine designs it may be desirable to inject all the fuel on the intake stroke under some load conditions. If the last part of the injection occurs during the compression stroke, the mixture in the auxiliary combustion zone will be somewhat richer than the mixture in the rest of the combustion chamber. The auxiliary and main combustion zones preferably are proportioned so that the maximum power output is attained when the last moiety of the fuel injected is introduced at the start of the compression stroke when the mean period of injection is fully advanced. As the mean period of injection is advanced, the amount of fuel injected is increased.

The following examples are given to illustrate the operation of an internal combustion engine of the general form shown in Fig. 1 in accordance with the principles of the invention. In these examples all the fuel is injected into the auxiliary combustion chamber and all the air is supplied through this chamber.

Example 1—Full Load Operation

For purposes of this example, it is assumed that the main combustion space 6 and the auxiliary combustion space 5 of the engine of Fig. 1 are of equal volume when the piston is at top dead center, the sum of the volumes totaling 150 arbitrary units. Moreover, it is assumed that the proper mixture for full load operation is 150 parts of air to 10 parts of fuel in the entire combustion chamber.

The injection of fuel is so timed that one-half of the fuel is introduced on the intake stroke of the piston and the remaining half is introduced on the compression stroke. At the end of the intake stroke there is a mixture in 5 and 6 consisting of 5 parts of fuel and 150 parts of air, or a 30 to 1 mixture. Five parts of fuel are introduced on the compression stroke, either directly into the auxiliary combustion zone or in the path of the mixture which the piston is forcing from the main combustion chamber to the auxiliary combustion chamber. At the time of ignition the mixture is distributed as follows: in the main combustion space there are 2.5 parts of fuel which were introduced on the induction stroke and 75 parts of air (30 to 1 mixture); in the auxiliary combustion space there are 7.5 parts of fuel, of which 2.5 parts were introduced during induction of air and 5. parts were added during compression, and 75 parts of air (10 to 1 mixture). In tabular form, the mixture distribution at the time of ignition appears below:

Combustion Space	*Air*	*Fuel*	*Mixture*
Main	75	2.5	30 - 1
Auxiliary	75	7.5	10 - 1
Entire	150	10.0	15 - 1

By varying the time of fuel injection with respect to the time of change-over from induction to compression, it is possible to obtain almost any desired ratio of fuel distribution between the two combustion spaces, within the limits of (1) uniform fuel distribution throughout the entire combustion zone to (2) no fuel in the main combustion zone and all fuel in the auxiliary combustion space. By injecting all of the fuel on the induction stroke, a uniform distribution of fuel throughout the entire combustion chamber results. By injecting all of the fuel on the compression stroke, substantially none finds its way into the main combustion space, substantially all of it remaining in the auxiliary combustion zone. Intermediate conditions of fuel distribution are obtained by varying the period of fuel injection so that the time of change-over from induction to compression occurs during the injection period.

The above example describes full load operation only, using a total mixture of 15 to 1. The advantage of operating at full load with two different mixture strengths in a common combustion chamber is that detonation is obviated or at least minimized. A relatively rich mixture is maintained in the vicinity of the ignitor to assure ready combustion while a relatively lean mixture exists in the rest of the combustion chamber remote from the ignitor to discourage detonation. This differential distribution is effected while charging fuel and air in proportions to give maximum power and most efficient results.

Example 2—Part Load Operation

In conventional induction type four-cycle engines, which induce a preformed air-fuel mixture from a carburetor or the like, reducing the amount of fuel without reducing the amount of air results in creating a leaner mixture. Therefore, if only 5 parts of fuel is added to 150 parts of air for low power output, a mixture of 30 to 1 results, which is too lean to ignite satisfactorily, if at all. Throttling may be employed to reduce the amount of air taken into the cylinder as the amount of fuel is reduced, but such throttling, by reducing the volume of air in the cylinder, necessarily results in a correspondingly low compression and greatly reduces the efficiency of conversion of the heat energy into useful work.

If in the engine of Example 1 the time of fuel injection is retarded so that all of the fuel (5 parts in this example) is introduced during compression, the combustible mixture will be localized in the auxiliary combustion space just prior to firing. At the time of ignition the fuel distribution between the auxiliary and main combustion spaces would be as follows:

Combustion Space	*Air*	*Fuel*	*Mixture*
Main	75	0	∞
Auxiliary	75	5	15 - 1
Entire	150	5	30 - 1

At the locus of ignition in the auxiliary combustion zone there would exist a readily ignitable mixture of 15 to 1.

In the main combustion space only air would be entrapped. By thus localizing the fuel adjacent the ignitor a lean average mixture of 30 to 1 effectively can be utilized without sacrificing compression by throttling air. Detonation also is overcome by having a leaner mixture existing in the combustion chamber remote from the point of ignition so that as the flame front radiates away from the point of ignition the unburned mixture in advance of it is always too lean to explode violently giving rise to detonation.

Example 3—Minimum Idling Conditions

This example, together with Examples 4 and 5, constitutes a series. In these last three examples the following conditions apply:

(1) Volume of entire combustion space = 150 units
(2) Minimum fuel required for idling = 2 parts
(3) Optimum mixture at locus of ignition at time of ignition = 15 - 1

The combustion chamber of the engine is proportioned so that the minimum fuel required for idling is contained entirely within the auxiliary combustion zone as a 15 to 1 air-fuel mixture at the time of ignition. This requires that the auxiliary combustion zone be one-fifth the total volume of the combustion chamber with the piston at top dead center, or, in other words, that it have a volume of 30 units. The structure of the chamber may be like that shown in Figs. 1 and 2 of the drawings with appropriate adjustment in the relative sizes of spaces 5 and 6.

Under idling conditions two parts of fuel are introduced into the auxiliary combustion zone on the compression stroke. The table immediately below illustrates the conditions obtaining in the combustion chamber at the moment of firing.

Combustion Space	*Air*	*Fuel*	*Mixture*
Main	120	0	∞
Auxiliary	30	2	15 - 1
Entire	150	2	75 - 1

Great fuel economy is obtained at idling conditions, for, in effect, an average air-fuel mixture of 75 to 1 is burned, which mixture in the absence of proper fuel distribution is practically non-combustible under the conditions of operation.

Example 4—Intermediate Operating Conditions

To operate the engine of Example 4 under an intermediate condition of power output, it will be assumed that 6 parts of fuel will provide the demand. The mean period of fuel injection is advanced until 5 parts of fuel are injected on the induction stroke and 1 part is injected on the compression stroke. This results in a fuel distribution at the time of ignition as set forth in the following table:

Combustion Space	*Air*	*Fuel*	*Mixture*
Main	120	4	30 - 1
Auxiliary	30	2	15 - 1
Entire	150	6	25 - 1

The optimum air-fuel mixture of 15 to 1 is maintained in the auxiliary combustion zone, and a much leaner mixture of 30 to 1 obtains elsewhere in the combustion chamber.

Example 5—Limiting Operating Conditions

The upper limit of power output of the engine consistent with providing a 15 to 1 mixture at the locus of ignition at the time of ignition is reached when 10 parts of fuel is injected into the auxiliary combustion zone entirely during the induction stroke of the engine. Substantially complete mixing and homogeneous distribution of the fuel in the air is thereby accomplished. At the moment of firing, the distribution of the mixture between the two spaces is as shown in the following table:

Combustion Space	*Air*	*Fuel*	*Mixture*
Main	120	8	15 - 1
Auxiliary	30	2	15 - 1
Entire	150	10	15 - 1

For maximum power output with a minimum of detonation, it may be desirable to reduce the total fuel injected to a value somewhat below 10 and to retard slightly the period of fuel injection to a point where the last portion of the fuel is injected on the compression stroke and substantially retained within the auxiliary combustion zone to keep the mixture strength there at 15 to 1. A somewhat lower mixture strength will then obtain in the main combustion space and detonation will thereby be minimized.

It may be desirable, at maximum power output, to provide a somewhat different adjustment of the mixtures existing in the two combustion spaces for minimizing detonation. Assuming that a 15 to 1 overall mixture strength is desired, 10 parts of fuel might be injected as follows: 8.75 parts during the induction phase and 1.25 parts during the compression phase of operation. At the time of ignition, then, the distribution under such operating conditions would be as shown in the table below:

Combustion Space	*Air*	*Fuel*	*Mixture*
Main	120	7	17.14 - 1
Auxiliary	30	3	10 - 1
Entire	150	10	15 - 1

A relatively rich mixture of 10 to 1 would obtain in the auxiliary combustion space and a leaner mixture of

17.14 to 1 would obtain elsewhere in the combustion space.

For the purpose of simplification, complicating factors, such as diffusion and convection, have not been expressly considered in the foregoing examples, but these factors do not alter the principles involved. In practice, a sharp boundary of demarkation between the mixtures in the main and auxiliary combustion spaces is not obtained. Instead a zone exists between the two spaces in which the transition between the mixture strengths is rather gradual. This is desirable because it tends to smooth out the propagation of the flame front through the combustion chamber.

In general, it may be said that fuel supplied on the intake stroke is uniformly distributed throughout both spaces of the combustion chamber while fuel injected on the compression stroke is substantially completely retained in the auxiliary combustion zone. However, this distribution may be somewhat modified in practice due to the many possible forms of double-spaced combustion chambers, the positioning and operation of the intake and exhaust valves, the location of the fuel injecting nozzle, and other factors. The most desirable construction of a combustion chamber for applying the method of this invention to the operation of internal combustion engines should enable the incoming air to pass through any fuel which is injected into the auxiliary combustion zone on the induction stroke of the motor, to effect uniform distribution of such fuel throughout the entire combustion chamber.

In the engine illustrated in Fig. 4, provision is made for the admission of air or of air-fuel mixtures both to the auxiliary combustion chamber and to the main combustion chamber. In Fig. 4, 11 represents the walls of the cylinder and 12 the piston of a four-cycle internal combustion engine. Cylinder head 13 encloses main combustion chamber 14 including an offset portion, as in conventional L-head engines. In the offset portion is a main intake valve 15 and an exhaust valve (not shown). The cylinder head 13 is provided with an auxiliary head 16 which may, for example, be fitted into the conventional spark plug opening and which provides an auxiliary combustion chamber 17 communicating with the main combustion chamber 14 through passage 18. The auxiliary head 16 is provided with a fuel injection nozzle 19, a spark plug 20, and an auxiliary intake valve 21. When air-fuel mixtures are admitted to the combustion chamber during the intake stroke through the intake valves, both main intake valve 15 and auxiliary intake valve 21 are preferably connected to a common manifold leading from a suitable air and fuel mixing device.

The following further examples are directed to the operation of an engine of the type shown in Fig. 4 in which the volume of the auxiliary combustion chamber is 20% of the volume of the entire combustion space at top center position of the piston. The examples are further particularly directed to show the control of the portion of fuel injected into the auxiliary combustion chamber during the compression stroke to provide non-detonating mixtures of fuel and air in the main combustion chamber under all conditions of power demand while maintaining an ignitable mixture in the auxiliary combustion chamber.

A total combustion chamber volume equivalent to 150 unit weights of air is assumed and the critical detonation zone is assumed to cover air-fuel mixtures of from 10 to 1 to 25 to 1.

Example 6—Full Load

At full load, half of the total fuel charge is supplied to the combustion chamber during the intake stroke, either by injection into the auxiliary chamber or by admission into the chambers in admixture with the air, and half the charge is injected into the auxiliary combustion chamber during the compression stroke.

Combustion	*Fuel Charge*		*Air-Fuel*
Space	*On Intake*	*On Compression*	*Ratio*
Auxiliary	1	5	5 - 1
Main	4	—	30 - 1
Total	5	5	15 - 1

Example 7—Full Load

At half load, half of the total fuel charge is again supplied during the intake stroke and half is injected into the auxiliary combustion chamber.

Combustion	*Fuel Charge*		*Air-Fuel*
Space	*On Intake*	*On Compression*	*Ratio*
Auxiliary	½	2½	10 - 1
Main	2	——	60 - 10
Total	2½	2½	30 - 1

Example 8—Low Load

At idling loads, the entire fuel charge amounting to 20% of the fuel charge at full load is injected into the auxiliary combustion chamber during the compression stroke.

Combustion	*Fuel Charge*		*Air-Fuel*
Space	*On Intake*	*On Compression*	*Ratio*
Auxiliary	—	2	15 - 1
Main	—	—	100% Air
Total	—	2	75 - 1

The variation in the time and period of injection in relation to crank angle and piston displacement for the conditions of Examples 6, 7 and 8 is shown diagrammatically in Fig. 5.

Fig. 6 is a graph showing the variation of air-fuel ratios with power output in the main combustion chamber and auxiliary combustion chamber in Examples 6, 7 and 8. This graph clearly shows how the presence of air-fuel compositions within the critical detonation zone is avoided both in the main and auxiliary combustion chambers at high loads, thus making possible the use of very high pressures and correspondingly increased power outputs without detonation even with relatively sensitive fuels.

For the sake of clarity and simplicity of exposition, the invention has been described as applied to an engine having only a single cylinder, but it is obvious that the invention applies equally to multi-cylinder internal combustion engines.

The fuel may be mixed with a small amount of air and injected through the nozzle. Preferably the amount of air used is insufficient to form a combustible mixture with the fuel. It is to be understood that the invention is not limited to operating with so-called "solid injection" of fuel.

The nozzle for injecting fuel specifically forms no part of the present invention. It may be any of the well known fuel injecting nozzles at present available, but preferably it should be capable of producing an extremely fine, almost gasified, spray of fuel.

Means for metering the fuel and timing the period of fuel injection preferably are synchronized to operate in phase with the engine and preferably are provided with means for varying at will the amount of fuel injected per cycle, together with means for varying the mean period of fuel injection with changing power demand upon the engine. Such means constitute no part of this invention and they may be of any known or desired type.

This application is a continuation-in-part of my application Serial Number 320,208, filed February 21, 1940.

I CLAIM:

1. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion

chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

2. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture and in the main combustion chamber a fuel mixture outside the critical detonating range under all conditions of power demand,

and igniting the mixture under compression in the auxiliary combustion chamber.

3. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

4. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during

the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture and in the main combustion chamber a fuel mixture outside the critical detonatng range under all conditions of power demand, and igniting the mixture under compression in the auxiliary combustion chamber.

5. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume from 0.1 to 0.5 the volume of the total combustion space at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the man combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

6. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communi-

cating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, injecting into the auxiliary combustion chamber controlled charges of fuel varied in timing and duration with respect to power demand upon the engine, at least a portion of said fuel charges being injected during the compression stroke in an amount varied in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

7. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount with respect to the relative sizes of the auxiliary and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

8. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount with respect to the relative sizes of the auxiliary and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

9. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, injecting into the auxiliary combustion chamber controlled charges of fuel varied in timing and duration with respect to power demand upon the engine, at least a portion of said fuel charges being injected during the compression stroke in an amount varied with respect to the relative sizes of the auxiliary and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

IN TESTIMONY WHEREOF, I affix my signature.

/s/ Neil O. Broderson

OATH

District of Columbia, ss

NEIL O. BRODERSON, the above-named petitioner, being duly sworn, deposes and says that he is a citizen of the United States, and a resident of Rochester, County of Monroe, State of New York; that he verily believes himself to be the original, first and sole inventor of the improvements in METHOD OF OPERATING INTERNAL COMBUSTION ENGINES, described and claimed in the annexed specification; that he does not know and does not believe that the same was ever known or used before his invention or discovery thereof, or patented or described in any printed publication in any country before his invention or discovery thereof, or more than two years prior to his application Serial No. 320,208, filed February 21, 1940, of which this application is a continuation-in-part, or in public use or on sale in the United States for more than two years prior to his application Serial No. 320,208; that said invention has not been patented in any country foreign to the United States on an application filed by him or his legal representatives or assigns more than twelve months prior to his application Serial No. 320,208; and that no application for patent on said improvement has been filed by him or his representatives or assigns in any country foreign to the United States; and that the subject-matter of the annexed specification which is not common to his application Serial No. 320,208, filed February 21, 1940, has not been patented or described in any printed publication in any country more than one year prior to this application, or in public use or on sale in the United States for more than one year prior to this application, or patented by him or his legal representatives or assigns in any country foreign to the United States on an application filed more than twelve months prior to this application.

/s/ Neil O. Broderson

SWORN TO and subscribed before me this 7th day of May, 1942.

/s/ Paul A. Rose
Notary Public

(SEAL)

My commission expires July 31, 1946.

* * * *

Paper No. 6

* * * *

Add the following claim:

10. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine, compressing the air within the combustion space, supplying to the combustion space controlled charges of fuel varied in amount in relation to the power demand on the engine, injecting into a portion of said combustion space during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the quantity of fuel supplied to effect a controlled segregation of fuel in said portion of the combustion space effective to provide in said portion of the combustion space an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture in the remainder of the combustion space, and igniting the mixture under compression in said portion of the combustion space.

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W = total weight of air
A = " " " in 5
F = " " fuel at full load
BF partial fuel quantity at less than full load

Fig. 1.

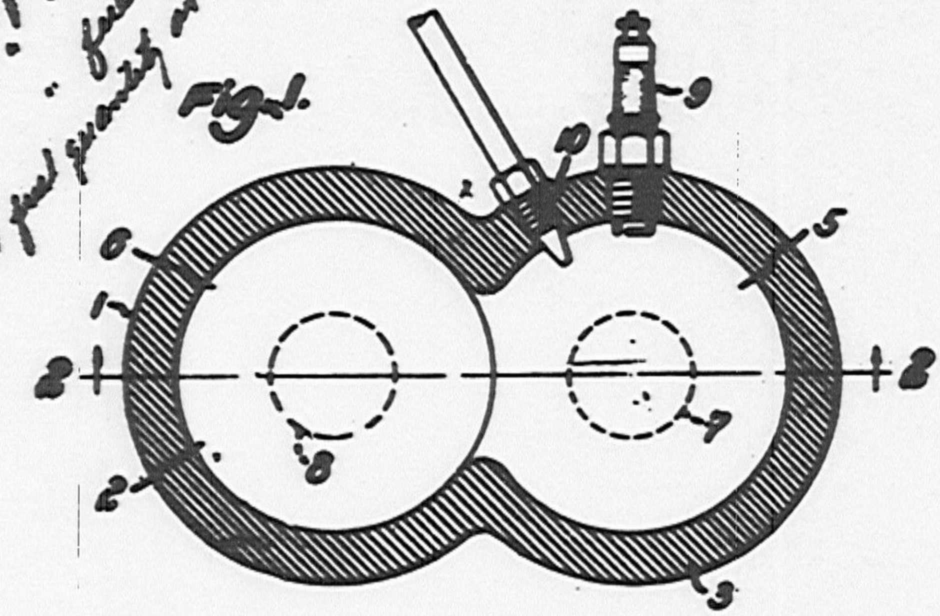
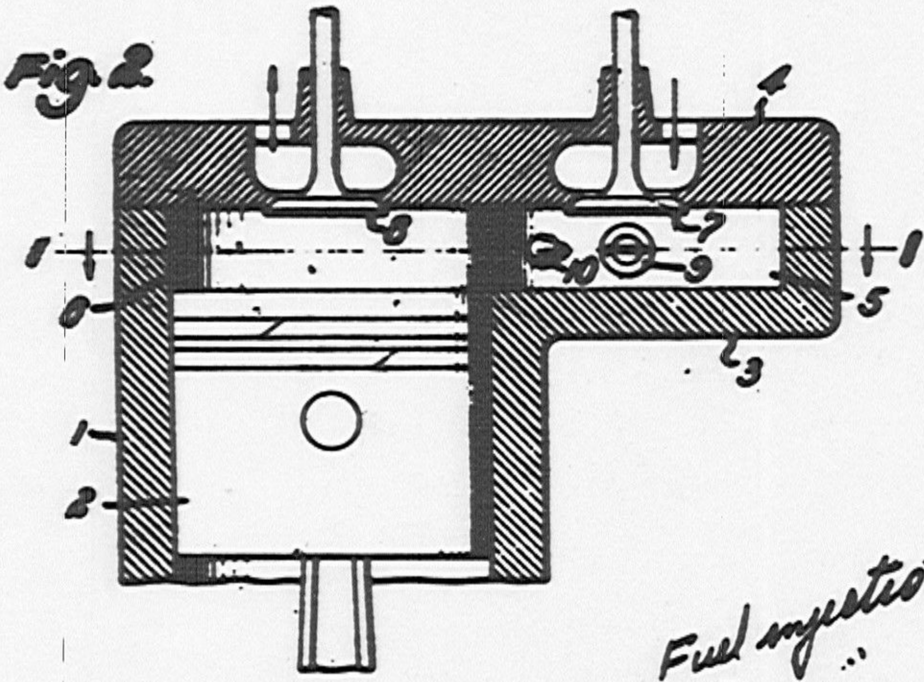
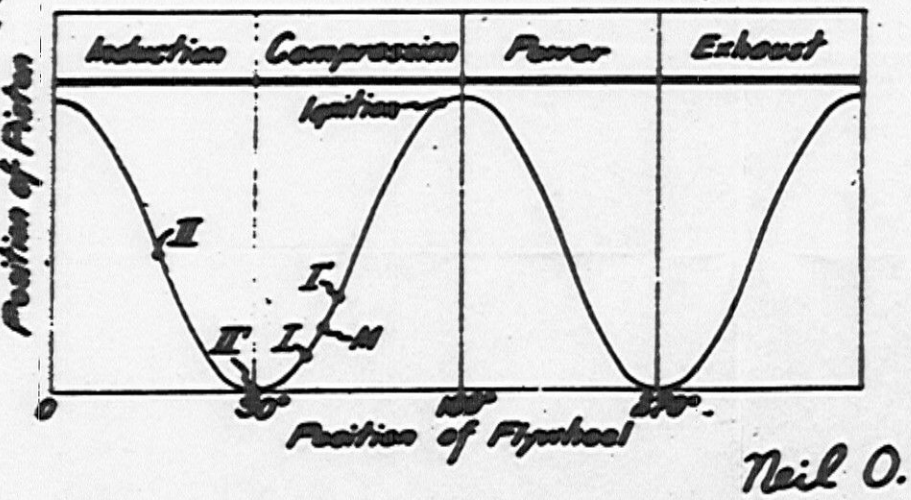


Fig. 2.



Fuel injection I-I' at idling
" " II-II' " load

Fig. 3.



Inventor:

Neil O. Broderson

By Pierce + Scheffler

Attorneys.

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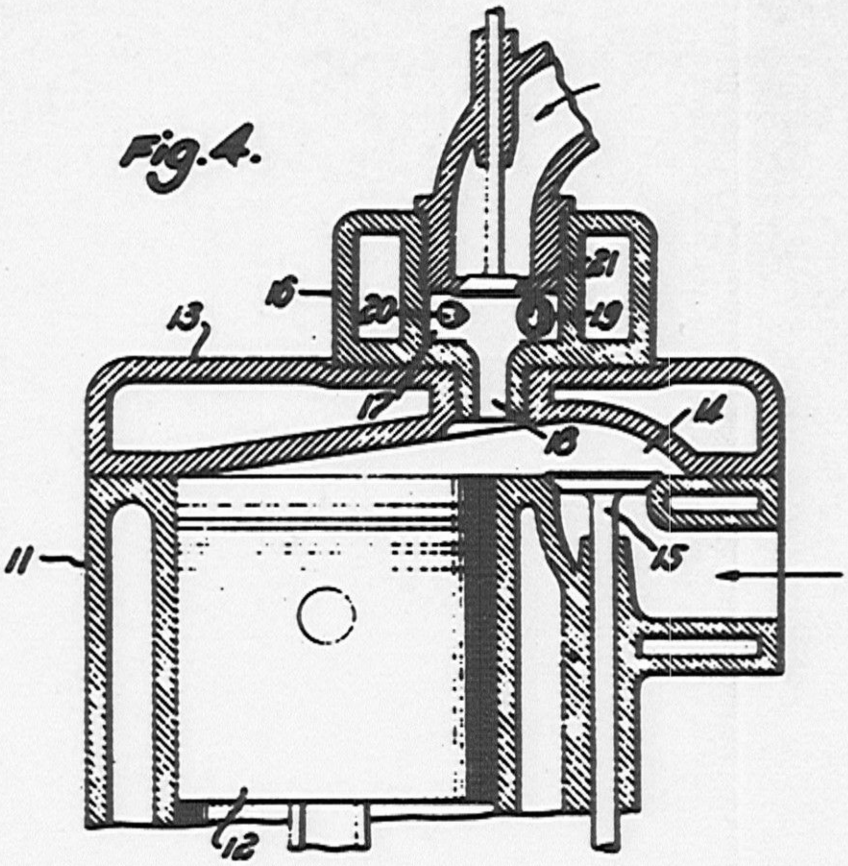
Fig. 4.



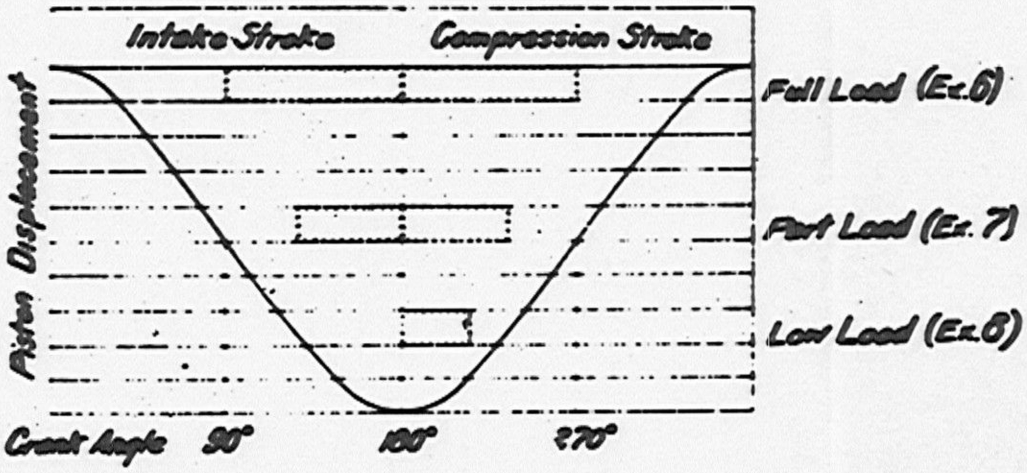


Fig. 5.

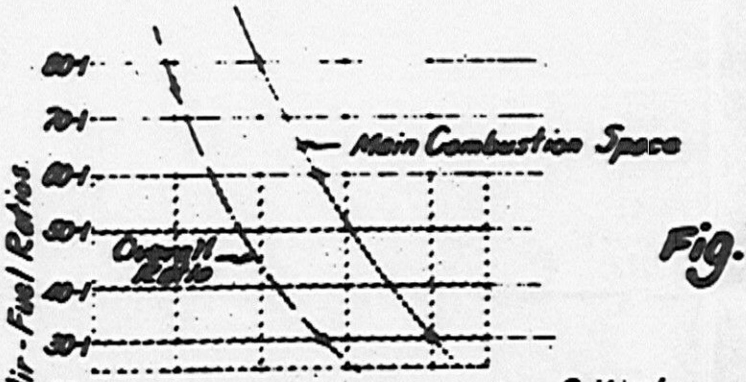


Fig. 6.

Inventor

Neil O. Brodersen

By

Pierce + Scheffler

Attorneys.

Division 28 Room 220 Paper No. 13

IN THE UNITED STATES PATENT OFFICE
RICHMOND, VIRGINIA
In re application of:
Neil O. Broderson
Serial No. 442,830
Filed: May 13, 1942
For: Method of Operating Internal Combustion Engines
On Appeal to the Board of Appeals

Examiner's Statement

This appeal is taken from the action of the Primary Examiner, finally rejecting claims 1-10, all the claims in the case.

The claims on appeal are as follows:

1. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main

combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

2. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture and in the main combustion chamber a fuel mixture outside the critical detonating range under all conditions of power demand, and igniting the mixture under compression in the auxiliary combustion chamber.

3. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the

compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in compostion of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

4. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture and in the main combustion chamber a fuel mixture outside the critical detonating range under all conditions of power demand, and igniting the mixture under compression in the auxiliary combustion chamber.

5. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in

part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume from 0.1 to 0.5 the volume of the total combustion space at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

6. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, injecting into the auxiliary combustion chamber controlled charges of fuel varied in timing and duration with respect to power demand upon the engine, at least a portion of said fuel charges being injected during the compression stroke in an amount varied in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and to provide in the auxiliary

combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

7. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount with respect to the relative sizes of the auxiliary and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

8. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine at least in part through an auxiliary combustion chamber communicating with a main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount with respect to the relative sizes of the auxiliary and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

9. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, injecting into the auxiliary combustion chamber controlled charges of fuel varied in timing and duration with respect to power demand upon the engine, at least a portion of said fuel charges being injected during the compression stroke in an amount varied with respect to the relative sizes of the auxiliary and main combustion chambers, to the power demand upon the engine and to the composition range of ignitable mixtures of the fuel in use, in accordance with the formula

$$X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke, V is the number of unit weights of air contained in the total combustion space at top center position of the piston, A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber, F is the unit weights of fuel supply per charge at full load, B is the amount of the load expressed as a fraction of the fuel supply at full load, and C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as the fuel fraction of the mixture, and igniting the mixture under compression in the auxiliary combustion chamber.

The alleged invention relates to a method of operating four-stroke cycle internal combustion engines of the type provided with an auxiliary pre-combustion chamber. As viewed in Figures 1 and 4, a conventional internal combustion engine is provided with an auxiliary combustion chamber 5-17 having continuous restricted communication with the main combustion chamber 6-14 and provided with a spark plug 9-20 and fuel injection nozzle 10-19. Fuel injection through the nozzle takes place at a desired period in the engine cycle to insure proper fuel-air mixtures in the main and auxiliary combustion chambers for efficient combustion.

The real point and gist of the alleged invention resides in the timing of the fuel injection to insure the desired proportioning of the total fuel charge between the two combustion chambers. It is stated that in the engines of prior design where combustion is initiated in the auxiliary combustion chamber at the spark plug, a flame front is generated which allegedly results in pre-ignition or "knock", because the fuel-air mixture is not segregated and proportioned to give a progressive combustion without tendency to detonate. As distinguished from prior practice, appellant alleges to have discovered that controlled segregation of fuel between the auxiliary and main combustion chambers to provide in the auxiliary combustion chamber an ignitable fuel mixture under all conditions of power demand, irrespective of variations in the composition of the fuel-air mixture, will result in smooth, quiet combustion and prevent "knock" or pre-ignition.

As more specific aspects of the alleged invention, it is stated that the proportioning of the fuel charge is expressed by the formula

$$\text{``}X = \frac{CAV - ABF}{BF - ABF}$$

in which X is the fraction of the fuel charge injected into the auxiliary combustion chamber during the compression stroke; V is the number of unit weights of air contained in the total combustion space at top center position of the piston (that is, V is the total volume of the combustion space expressed in unit weights of air); A is the fraction of the total combustion space at top center position of the piston contained in the auxiliary combustion chamber (A is preferably not substantially outside the range 0.1 to 0.5); F is the unit weights of fuel supply per charge at full load; B is the amount of the load expressed as a fraction of the fuel supply at full load (thus BF is the unit weights of fuel per charge at any fraction of full load); C is the composition of the fuel mixture in the auxiliary combustion chamber, selected from the ignitable range of mixtures of the fuel in air, expressed as a fraction of the mixture of air and fuel. C will vary with the particular fuel used and for any particular fuel can be selected from a definite range of values. Advantageously C is so selected as to provide a non-detonating fuel mixture in at least the main combustion chamber."

Figure 3 shows in graph form the operating adjustments of fuel injection "in accordance with the invention." At idling engine speeds and loads the entire fuel injection is carried out during the compression stroke of the piston. The injection period is indicated by I—I'. With increased load the beginning of injection is advanced to begin during the intake stroke. Appellant states that it is the "mean period of fuel injection" that should be advanced with increased fuel supply due to increased load demand. It is stated that such increased injection may be accomplished by advancing the beginning of injection keeping the rate of injection and the ending constant or the beginning and ending may be advanced with an increased fuel supply as shown at II—II'.

The real gist and point of the alleged invention appears to reside in the proper timing of the fuel injection period so as to insure an ignitable mixture at the spark plug at all load conditions and properly proportioned mixtures in the main and auxiliary combustion chambers so that the remainder of the fuel charge will burn without knocking.

The references relied on are:

Yost et al	1,096,585	May 12, 1914
Power	1,235,725	Aug. 7, 1917
Werner	1,616,157	Feb. 1, 1927
Hesselman	1,835,490	Dec. 8, 1931
Wild et al	2,005,063	June 18, 1935
Starr	2,025,362	Dec. 24, 1935
Bremser	2,061,826	Nov. 24, 1936
Mock	2,142,280	Jan. 3, 1939
Dillstrom	2,145,250	Jan. 31, 1939
Chapman	2,204,068	June 11, 1940
British Patent	195,609	Jan. 31, 1924
British Patent	373,647	May 17, 1932
Swiss Patent	208,611	

Before considering any of the references, Examiner wishes to call the attention of the Board of Appeals to the fact that it is elementary knowledge in present day engine design that pre-ignition knock is due to compression of unburned combustible mixture by the pressure wave in front of the flame front to a pressure and temperature at which spontaneous ignition takes place. It is also elementary knowledge that by regulation of the progress of the flame front and the proper proportioning of the fuel-air mixture a controlled, smooth and efficient combustion, without pre-ignition knock, can be secured. The endeavor of the engine designer is directed to the creation of a combustion chamber of a structure, or a method of combustion, which would produce the above well known desideratums.

Yost 1,096,585 and Chapman 2,204,068 were cited to illustrate the segregation or proportioning of the total fuel charge between two combustion chambers by the use of two separate fuel jets of proper size. In engines provided with more than a single fuel jet it is quite common to vary the rate of injection of one jet relative to the other with change in load and/or speed in order to insure proper fuel-air ratio for the zone served by each of the jets (see Mock 2,012,086 of August 20, 1935).

Power 1,235,725 and Dillstrom 2,145,250 patents were cited to illustrate the common expedient in the engine design of varying the timing of fuel injection with engine load. Power describes a spark ignition engine and suggests the adjustment of fuel injection timing with respect to load by varying the point of beginning of the injection and/or the point of ending (page 3, lines 9-20). Dillstrom's disclosure relates to a compression ignition engine and teaches the variation of the timing of the fuel with changes in speed (and load) to insure complete and efficient combustion.

Werner 1,616,157 was cited to illustrate engine design utilizing two separate combustion chambers communicating by means of a restricted passageway and having fuel stratification or proportioning carried out by means of separate fuel injection into the combustion chambers. Ignition takes place in the auxiliary combustion chamber K and the flame spreads to the main combustion chamber 21 where controlled burning is carried out. The proportioning of the total fuel charge between main and auxiliary chamber is secured by proper timing of the fuel injection pump (see page 8, lines 14-121).

Hesselman 1,835,490 was cited to illustrate the adjustment of fuel injection timing with load variation in an engine designed for fuel-air proportioning to insure a properly ignitable mixture at the spark plug and uniformly burning mixture in the remaining portion of the charge. (See Figures 7, 8, 9 and 18.

Wild et al 2,005,063 was cited merely to further illustrate the variation in the timing of fuel injection with a change in engine operating characteristics to insure proper fuel-air ratio for a given engine condition. Patentee times his fuel injection for starting at 54° before top dead center and changes the timing to given injection at 58° after the beginning of the suction for normal engine operation.

Starr 2,025,362 and Swiss patent 208,611 illustrate a spark ignition injection engine where a predetermined stratification of fuel in the air charge is relied on to insure the desired fuel-air mixtures at the desired zones of the combustion chamber (see page 1, lines 11-35 and page 4, lines 11-74).

Bremser 2,061,826 was cited to illustrate the engine structure comprising main and auxiliary combustion chambers 13-21 connected by means of a restricted passage 46. Fuel injection nozzle 14 is arranged to direct a predetermined proportion of the fuel charge into the auxiliary chamber 21 where it is ignited by the spark plug 11 and as the fuel burns, the flame front progresses to the main combustion space defined by the depression in the piston and cylinder heads. Patentee states that he prefers to begin the injection "approximately 60 degrees before top dead center position of the piston, a predetermined quantity of fuel in proportion to load demands on the engine, is delivered by a usual fuel injection pump" (page 2, column 1, lines 60-65). The segregation and proportioning of the fuel to insure combustible mixture at full and part loads is secured by the proper timing and quantity control of the fuel injection (see page 2, column 2, lines 2-39).

Mock 2,142,280 was cited to illustrate the application of the above mentioned features of design. Patentee fully teaches the idea of providing the engine with main and auxiliary combustion chambers and timing the fuel injection in such a manner that stratification is produced "to avoid the possibility of the flame front of the burning charge trapping explosive mixture against a wall where such mixture might be detonated by compression" (page 1, lines 41-44). Patentee illustrates the auxiliary combustion chamber 15 in continuous restricted communication with the main combustion chamber by means of the passage 16 and times his fuel injection "during the late exhaust or early intake stroke of the piston" to insure proper proportioning of the fuel to prevent detonation "the requirement being that the fuel must not enter *too greatly* into the piston displacement chamber" (page 2, column 1, lines 70-74). Fuel injection may also occur during the compression stroke and is timed to give a predetermined stratification of fuel-air mixture to insure the predetermined type of flame propogation (page 2, column 2, lines 37-70).

British Patent 195,609 was cited to illustrate an auxiliary cambustion chamber in restricted communication with the main combustion chamber but of smaller volume than the latter. The ignition takes place in the auxiliary chamber and the fuel is timed and regulated to give desired proportions in the two chambers (page 2, lines 5-49).

British Patent 373,647 was cited to illustrate the use of an auxiliary chamber which is one half of the total clearance area (page 1, lines 96-100).

Examiner rejected all the claims in this application in the following manner:

"The operation of a four-stroke internal combustion engine by dividing the charge of air between two combustion chambers and injection of the fuel into the chambers in proper proportions to insure an ignitable mixture in the desired chamber is an expedient notoriously old and common. Bremser initiates ignition in the auxiliary combustion chamber in communication with the engine cylinder. The same is true of Yost, Swiss patent 208,611 and British patent 195,609. The Fischer, Ramsey and Lang patents proportion the relative mixtures so as to have combustion initiated in the main engine cylinder. Thus, whether ignition is initiated in the main or auxiliary combustion chambers is a mere matter of design.

"Applicant places a great stress on the fact that Bremser's patent shows an auxiliary combustion chamber which is apparently of greater volume than the main combustion space in the engine cylinder when the piston is at the top dead center. It is stated that Bremser in effect has "substantially the whole combustion chamber" in his chamber 28. Such obviously is not the fact, as the patentee clearly shows a combustion space 31 in the engine cylinder.

"It is a notoriously old and common expedient to proportion the charge in an auxiliary combustion chamber so as to insure ignition therein, and it is a common expedient of precombustion chamber engines. See Yost, page 2, column 1, lines 59-65. It is also an old and notoriously common expedient to proportion the fuel injection between the main and auxiliary combustion chambers by proper location and timing of injection nozzle, (Bremser, Ramsey, British patent 195,609 and Swiss patent), or by individual fuel jets (Chapman patents and Mock).

"Applicant states that the Examiner is not justified in combing the prior art for individual features and combining them, regardless of the underlying principles of operation. Such does not appear to be the case, since it is the Examiner's opinion that there is no new or different mode of engine operation. On the contrary, it appears that applicant has searched in the prior art and selected from it various old and well known features and combined them into a single engine assembly, producing only the sum of the expected results of the individual features without producing any new or unexpected unitary result.

"Rejection of claims 1-9, as being unpatentable over Bremser or the British patent is hereby repeated. It is still the Examiner's opinion that the relative size of an auxiliary combustion chamber is a mere matter of design, and that no invention is required to form Bremsers combustion chamber 28 of any desired volume. The chosen size for the combustion chamber 28 may be smaller or larger than the volume of the main combustion chamber, as desired.

"Claims 1-9 are further rejected as being unpatentable over any one of the Chapman patents, for the reason that no invention would be required to initiate the combustion in the auxiliary chamber (the chamber not in direct communication with the engine cylinders), and to proportion such chamber to give any desired volume.

"Claims 1-9 are further rejected as being unpatentable over the Swiss patent whose engine will operate in accordance with the method claimed.

"Claims 1-9 are further rejected as being unpatentable over Yost et al, whose ignition chamber 18 is considered the full mechanical equivalent of applicant's auxiliary chamber 5, insofar as the patentability of a method claim is involved.

"Claims 1-9 are further rejected as being unpatentable over Bremser for the reason that no invention would be required to intiate combustion in the auxiliary chamber 9, in the manner suggested by Bremser.

"Claims 1-9 are further rejected as being unpatentable over Mock, for the reason that no invention would be required to proportion the auxiliary combustion chamber relative to the cylinder space so as to provide a smaller volume for said chamber, in the manner suggested by Yost and Britsh patent 195,609."

It is the Examiner's position that no new method of operating a four-stroke cycle internal combustion engine has been disclosed. It is a notoriously old and common expedient in the design of internal combustion engines to consider such elements as flow and turbulence of the air charge, the degree of penetration and direction of the fuel jet, the timing of injection with respect to the load and speed of the engine, the location of the spark plug, the shape of the combustion chamber, etc., in timing and adjusting the fuel injection to insure desired fuel-air ratios at the desired points and at the correct time. In adjusting and determining the timing of fuel injection so as to insure proper stratification between different portions of a combustion chamber or combustion chambers, where auxiliary chambers are used, it is common to shift the timing of injection around the entire 360° to select the proper timing for smooth combustion. In sustaining this position of the Examiner the Court of Customs and Patent Appeals stated that:

"The patentable novelty claimed because of the particular timing of fuel injection, we think, is disposed of by the Examiner who stated as follows:

'* * * It is elementary in injection engine design to time the beginning of fuel injection with reference to such factors as crudeness of the fuel used, combustion chamber design, fuel atomization, fuel heating and vaporization, speed of engine, etc. It is also a notoriously old and common expedient in engine design to reduce the ignition lag by pre-conditioning of the fuel charge for combustion by such means as preheating of the fuel, atomization of the fuel, mixing by whirling of the air charge, early injection to insure sufficient period in crank angle duration for heating, vaporization and mixing, etc. It was held that to time the injection of Saurer's engines to begin prior to the entry of the nozzle tip into the restricted opening, insuring partial injection into the main combustion chamber, is nothing more than a feature of engine design devoid of any inventive concept, particularly in view of French.'

"In view of the references, we fail to see how invention is involved in the alleged new and advantageous results obtained by the timing of the fuel injection and the character thereof." (In re Saurer 48 U. S. P. Q. 78). 529 OG 802

The decisions of the Court of Customs and Patent Appeals in In re Lang 113 F. (2d) 132; and In re Lang 82 F. (2nd) 399, 486 O. G. 783; are also in point.

Respectfully,
/s/ K. J. Albrecht
Acting Examiner, Div. 28

BHF:kw

Paper No. 18

Appeal No. 10,207
Hearing:
April 28, 1947

IN THE UNITED STATES PATENT OFFICE

BEFORE THE BOARD OF APPEALS

Ex parte Neil O. Broderson

Decision

Application for Patent filed May 13, 1942, Serial No. 442,830. Method of Operating Internal Combustion Engines.

Messrs. Stowell & Evans for appellant.

This is an appeal from the action of the Primary Examiner rejecting claims 1 to 10, which are all of the claims in the application.

Claim 1 is illustrative and reads as follows:

1. The method of operating a four-cycle internal combustion engine which comprises admitting constant charges of air to the combustion space of the engine including a main combustion chamber and an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage and having a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston, compressing the air within the combustion chambers, supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine, injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber and

to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber, and igniting the mixture under compression in the auxiliary combustion chamber.

The references relied on are:

Yost et al	1,096,585	May 12, 1914
Power	1,235,725	Aug. 7, 1917
British patent	195,609	Jan. 31, 1924
Werner	1,616,157	Feb. 1, 1927
Hesselman	1,835,490	Dec. 8, 1931
British patent	373,647	May 17, 1932
Wild et al	2,005,063	June 18, 1935
Starr	2,025,362	Dec. 24, 1935
Bremser	2,061,826	Nov. 24, 1936
Mock	2,142,280	Jan. 3, 1939
Dillstrom	2,145,250	Jan. 31, 1939
Swiss patent	208,611	May 16, 1940
Chapman	2,204,068	June 11, 1940

The claims are directed to a method of operating a four-cycle internal combustion engine. The engine, as disclosed in Fig. 2 of the application, is provided with a main combustion chamber 6, which is defined as located between the top of the piston 2 in its uppermost position and the cylinder head 4, and an auxiliary combustion chamber 5. The volume of the auxiliary combustion chamber is not substantially larger than that of the main combustion chamber and is separated therefrom by a slight restriction as shown in Fig. 1. An exhaust valve 8 is located in the cylinder head and an intake valve 7, a fuel injection nozzle 10 and an igniter 9 are located in the auxiliary combustion chamber. It is disclosed that a part of the total fuel supplied for each stroke may be separately injected into the auxiliary combustion chamber during the compression stroke of the piston, the remaining portion being injected during the induction or suction stroke. The engine is operated by admitting constant charges of air into the combustion space during the suction stroke and it appears that the portion of the fuel injected during the suction stroke may be brought in with the charge of air. By control of the timing and proportion of fuel injected at the two portions of the four-stroke cycle, applicant alleges that detonation is avoided.

In a paper filed April 28, 1947, appellant requested that the appeal be dismissed as to claim 10. This request will be granted.

The Primary Examiner has made a general rejection of all of the claims as unpatentable over individual ones of the thirteen references cited in his statement and also has referred to a fourteenth reference on page 9 of his statement. It does not appear that this fourteenth reference was cited in any of the actions on the application. We have, therefore, not considered this additional reference and from our consideration of the numerous references cited in the Examiner's Statement, it is found that only the patents to Mock, Werner and British patent 373,647 need be commented upon in detail.

The patent to Mock discloses a four-cycle internal combustion engine including a main combustion chamber, which is formed between the top of the piston 9 at its uppermost position, the underside of the piston head and the restriction 16, and an auxiliary combustion chamber 15 communicating with the main combustion chamber through a restricted passage 16. This engine is operated on a four-stroke cycle, the exhaust stroke being referred to on page 2, second column, lines 23 and 24, the suction stroke in line 36 and the compression stroke in line 70 of the same page and column. The step of admitting constant charges of air into the combustion space as recited in claim 1, for example, is performed during the suction stroke. During the compression stroke the air within the combustion chambers is compressed in accordance with the usual practice. The step of supplying to the combustion chamber controlled charges of fuel varied in amount in relation to the power demand upon the engine is the usual supply of fuel in accordance with the demand utilized in every internal combustion engine. The step of injecting a portion of the fuel charge during the compression stroke is clearly disclosed on page 2, second column, lines 3, 4 and 5 in which it is stated that that the remainder of the fuel charge is injected just prior to ignition. This fuel charge is injected into the auxiliary combustion chamber 15 through the nozzle 18. The step of igniting the mixture is performed through operation of the ignition device 20 and 21. It is clear therefore that all of the method steps recited in claim 1 are disclosed in the Mock application and that the only feature whereby this claim may be said to differentiate from the Mock patent is in the structural limitation to the effect that the volume of the auxiliary chamber does not exceed the volume of the main combustion chamber at top center position of the piston. It appears from the Mock disclosure that the auxiliary combustion chamber 15 is much larger than the main combustion chamber. We do not find it inventive, however, to apply the process clearly disclosed in the Mock patent to an engine in which the auxiliary combustion chamber is not larger in volume than the main combustion chamber in view of the British patent which clearly discloses that feature as pointed out by the Primary Examiner. It is also disclosed in the Werner patent and furthermore, we find the method recited in claim 1 disclosed in the Werner patent so that the claim is unpatentable over that patent without the use of any auxiliary reference. The Werner patent discloses an internal combustion engine which combines Otto cycle and Diesel cycle operation. It discloses a four-stroke cycle, the suction stroke being referred to on page 2, line 69 and the compression stroke on page 2, line 82. The step of admitting constant charges of air is disclosed on page 2, line 73. The engine includes a main combustion chamber R and an auxiliary combustion chamber K communicating with the main combustion chamber through a restricted passage 20 and the volume of the auxiliary combustion chamber K is smaller than the volume of the main combustion chamber at top center position of the piston as clearly shown in Fig. 1. The step of compressing the air within the combustion chambers is disclosed on page 2, lines 82 to 89. The supplying of charges of fuel varied in amount in relation to the power demand of the engine includes the supplying of fuel through the carburetor M and the injector nozzle N. A portion of the fuel is injected into the auxiliary combustion chamber during the compression stroke as indicated on page 2, lines 90 to 95. Although the fuel sprayed from the nozzle N may not be admitted directly into the auxiliary chamber K, such fuel may be admitted into the auxiliary chamber through the nozzle N′, if the auxiliary carburetor M is not being used as stated in the sentence commencing on page 2, line 65. The ignition step is disclosed in the sentence commencing on page 2, line 105. The variation of the amount of fuel injected at the various parts of the cycle for the purpose of avoiding detonation is considered a matter of adjustment and within the scope of knowledge of the skilled mechanic and we do not find claim 1 to distinguish from the prior art by reason of the effect of the recitation of the relation of the quantity of fuel charged at the various times in the cycle.

We therefore find claim 1 unpatentable over the prior art and we also find claims 2, 3, 4, 5, 6, 7, 8 and 9 unpatentable for the same reasons. We do not believe that any invention over this prior art is imported into such claims as claims 7, 8 and 9 by the inclusion of the specific formula specifying the proportions of the parts of the fuel charge. It is noted that claims 6 and 9 by including the phrase "at least a portion of said fuel charges being injected during the compression stroke" do not distinguish from a process in which all of the fuel is injected during that time.

The appeal is dismissed as to claim 10 and the decision of the Primary Examiner, for the reasons stated, is affirmed as to claims 1 to 9 inclusive.

In event of appeal attention is directed to *In re* Boyce, 32 CCPA 718; 144 Fed. (2d) 896; 1944 C. D. 609; 568 O. G. 568; 63 USPQ 80; in regard to specifically including in the appeal notice all grounds of rejection in the Examiner's Statement not expressly overruled by the Board.

/s/ V. I. Richard
Examiner-in-Chief
/s/ H. H. Jacobs
Examiner-in-Chief
/s/ Alden E. Imus
Examiner-in-Chief
Acting
BOARD OF APPEALS

May 26, 1947
Messrs. Stowell & Evans,
1420 New York Avenue, N. W.,
Washington, 5, D. C.

Request for Reconsideration

Hon. Commissioner of Patents
Washington, D. C.
SIR:

It is respectfully requested that the decision of the Board of Appeals, dated May 26, 1947, in the above-entitled application be reconsidered and revised for the reason set forth below.

1. *The Combination of the Mock patent and British patent 373,647.*

The holding of the Board that it would not be inventive to apply the process of the Mock patent to an engine in which the auxiliary combustion chamber is not larger in volume than the main combustion chamber in view of the British patent is erroneous.

The Mock method cannot maintain high efficiencies at low power demands, which is one of the purposes and advantages of applicant's method, for the reason that with the large ratio of the volume of the auxiliary combustion chamber to the main combustion space of Mock, he *must* reduce the volume of air charged to the cylinder at any power demand substantially below full load. If he did not make such a reduction in air charge he would not have an ignitable mixture in his auxiliary chamber wherein ignition is initiated.

It will be apparent from Fig. 6 of the Mock patent that he contemplates that the auxiliary ignition space will be substantially the entire combustion space at the time of ignition except for a small cushioning space just above the piston. Therefore, at half load, for example, if he did not substantially reduce his air charge, the air-fuel ratio in the ignition space would be considerably below the ignition ratio.

All of the claims of the application, in addition to defining that an ignitable fuel mixture is provided in the auxiliary combustion chamber *under all conditions of power demand,* also define the relation of auxiliary combustion chamber volume which makes this provision of ignitable mixtures possible while maintaining constant air charges, *without which high efficiency under conditions of low power demand is impossible.*

It is erroneous to say that this relation of auxiliary ignition space to main combustion space can be taught with respect to Mock's method of operation by the British patent because of the vitally different conditions of operation of the Diesel type of engine to which the British patent is directed. In this type of engine operation there is no question of the formation of an ignitable mixture of air and fuel in a given space. On the contrary, the combustion process is in the nature of a surface combustion at the surface of the particles of fuel sprayed into the cylinder and occurs over a measurable period of time, which is relatively very long compared to the period of combustion in an Otto cycle engine.

Moreover, claims 3 to 6 and 8 define that the constant charges of air are admitted "at least in part *through*" the auxiliary combustion chamber which ensures that the auxiliary combustion chamber cannot form a dead end trapping combusted gases from a previous cycle as in Mock and the British patent, thereby reducing if not eliminating effective control over the fuel-air ratio in the ignition space.

2. *The Werner patent.*

This method of operation of this patent is not properly comparable with that of the invention. Being, as the Board has said, a combination of Otto and Diesel cycle operation, the injection of fuel into the cylinder is continued after the initial ignition to provide a period of combustion at constant pressure.

There is no disclosure in this patent of controlling the portion of the fuel charge injected into the auxiliary combustion space to provide in said space an ignitable mixture under all conditions of power demand; still less is there a disclosure of such control within the limits of the formula set forth in claims 7, 8, and 9.

In this patent also, as in the Mock and British patents, admission of at least part of the air charges through the auxiliary combustion chamber is not disclosed.

In an engine operating with at least part of the fuel supplied during the outward travel of the piston, that is under conditions of substantially constant pressure, the question of knocking is by no means critical as it is under constant volume ignition conditions. Any tendency to detonate in the Werner operation is confined to the portion of the fuel ignited at constant volume and this is overcome by an expedient contrary to applicant's teaching, that is, by trapping burnt gases in the retort K (page 4, lines 39-49).

It is earnestly submitted that the Mock patent does not disclose or suggest the characteristic features of applicant's method of engine operation, and that the Diesel type operation of the British patent and mixed type operation of the Werner patent are not analogous to applicant's method of operation and neither disclose the invention nor suggest modification of the operation of Mock in the direction of applicant's method.

Reconsideration of the decision and reversal of the final rejection are therefore requested.

Respectfully,
/s/ Stowell & Evans
Attorneys for Applicant

Washington, D. C.
June 16, 1947

* * * *

Paper No. 20

Appeal No. 10,207

IN THE UNITED STATES PATENT OFFICE

BEFORE THE BOARD OF APPEALS

Ex parte Neil O. Broderson

Application for Patent filed May 13, 1942, Serial No. 442,830. Method of Operating Internal Combustion Engines.

Messrs. Stowell and Evans for appellant.

On Request for Reconsideration

The record before us does not establish that the method disclosed in the application on appeal can maintain high efficiencies at low power demands to an extent not attainable by the methods disclosed in the prior art. We do not find in the patent to Mock 2,142,280 any indication that the volume of air charged to the cylinder at any power demand substantially below full load must be reduced or that an ignitable mixture would not be present as contended by appellant. Engines may be designed without invention to widely vary the proportions of the main and auxiliary combustion chambers as is amply demonstrated by the numerous references cited by the Primary Examiner. The modification disclosed in Fig. 6 of the Mock patent, for example, discloses provision for admitting air through the auxiliary combustion chamber.

The requent is denied in respect to making any change in our decision.

/s/ V. I. Richard
Examiner-in-Chief
/s/ H. H. Jacobs
Examiner-in-Chief
/s/ Alden E. Imus
Examiner-in-Chief
Acting
BOARD OF APPEALS

No. 10,631

BRIEF FOR APPELLANT

United States Court of Appeals

FOR THE DISTRICT OF COLUMBIA CIRCUIT

NEIL O. BRODERRSON,
Appellant,

vs.

JOHN A. MARZALL, COMMISSIONER OF PATENTS,
Appellee.

United States Court of Appe
For the
District of Columbia Circuit

FILED AUG 31 1950

Joseph W. Stewart
CLERK

Appeal from the United States District Court for the District of Columbia

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Attorney for Appellant.

WILSON - EPES PRINTING CO. - RE 6003 - WASHINGTON 1, D. C.

No. 10,631

APPELLANT'S STATEMENT OF QUESTION PRESENTED

The question is whether, in an action against the Commissioner of Patents for the issuance of a patent, the evidence of novelty and inventiveness submitted on behalf of the plaintiff did not clearly and convincingly establish that the refusal of the Commissioner to issue a patent was erroneous.

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In The

United States Court of Appeals

For the District of Columbia Circuit

No. 10,631

Neil O. Broderrson,
Appellant,

vs.

John A. Marzall, Commissioner of Patents,
Appellee.

Appeal from the United States District Court for the District of Columbia

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BRIEF FOR APPELLANT

JURISDICTIONAL STATEMENT

This is an appeal from a decision of the District Court of the United States for the District of Columbia dismissing a complaint brought by Neil O. Broderson against John A. Marzall (substituted for Lawrence C. Kingsland) in his official capacity as Commissioner of Patents of the

United States Patent Office for the issuance of a patent on an application of said Broderson.

The District Court had jurisdiction of the complaint under the provisions of the Revised Statutes, Sec. 4915, U. S. C., Title 35, Sec. 63, (Complaint, paragraph 1, App. 2). This Court has jurisdiction of this appeal under the provisions of U. S. C., Title 28, Sec. 1291.

STATEMENT OF THE CASE

The complaint requests that the Commissioner of Patents be directed to issue a patent to plaintiff upon an application for Letters Patent, Serial No. 442,830 for improvements in ''Method of Operating Internal Combustion Engines'', filed in the United States Patent Office on May 13, 1942 as a continuation-in-part of a prior application, Serial No. 320,208, filed on February 21, 1940. The complaint is directed particularly to claims 1 to 9 of said application Serial No. 442,830 (App. 4-10).

The invention involved relates to a method of operating internal combustion engines to obtain increased efficiency, particularly at partial loads. It comprises admitting air to the combustion chamber of the engine and compressing the air, within the combustion chamber, injecting into an auxiliary combustion space, communicating with the main combustion chamber and not exceeding in volume the volume of the main combustion chamber at top dead center position of the piston, controlled charges of fuel, increasing in amount with increasing power demand upon the engine, during a controlled period of time comprised between the beginning of induction and the completion of compression, thereby effecting a differential distribution of fuel between the auxiliary combustion zone and the remaining portion of the combustion chamber so as to provide in the auxiliary combustion zone an ignitable fuel mixture at the time of ignition under all conditions of power demand and igniting the mixture under pressure in the auxiliary combustion zone.

All of the claims were finally rejected by the Examiner as unpatentable over thirteen prior patents (App. 148).

The final rejection of the claims was affirmed by the Board of Appeals of the Patent Office (App. 164) with particular reference to the following prior patents:

U. S. Patent No. 2,142,280—Mock (App. 97)
U. S. Patent No. 1,616,157—Werner (App. 101)
British Patent No. 373,647 (App. 114)

In appellee's answer to the complaint, appellee relied on the reasons given by the Examiner in his statement and in the decisions of the Board of Appeals on May 26, 1947 and June 30, 1947. At the trial the attorney for appellee stated that appellee relied particularly on the three prior patents above noted (Finding of Fact 3, App. 17) and no other prior patents were specifically referred to in behalf of appellee at the trial.

Evidence not available in the record before the Board of Appeals was presented on behalf of applicant at the trial. This evidence established the increased efficiency of the method of the invention over the conventional method of operating spark-ignition internal combustion engines, and established by the testimony of experts in the field of internal combustion engines the differences between appellant's invention and the disclosures of the prior art, and the great practical importance of these differences.

The District Court dismissed appellant's complaint, holding that the claims in suit were unpatentable in view of the United States patents to Mock and Werner and the British Patent No. 373,647 (App. 16-19).

STATEMENT OF POINTS RELIED ON

Appellant contends that the decision of the District Court is erroneous, as a matter of law, because the uncontradicted testimony and evidence offered by appellant showed beyond any reasonable doubt that appellant's method involves a principle of operation not disclosed or suggested by the prior art patents and that appellant's novel principle of operation leads to valuable and important improvements in the operation of internal combustion engines not attainable with conventional methods of operating spark-ignition engines.

SUMMARY OF ARGUMENT

The uncontroverted testimony of experts in the automotive field submitted on behalf of appellant clearly and convincingly showed that appellant's method of operating internal combustion engines leads to very substantial increase in efficiency of power production, particularly at partial loads; it showed that the method of operation invented by appellant is not disclosed in or suggested by the prior patents; and it showed that the decision of the Board of Appeals was based on clearly erroneous interpretations of the disclosures of the prior art. This uncontroverted evidence, which was not before the Patent Office tribunals, was clearly of such character and weight as to require the District Court to find that the decisions of the Patent Office tribunals were erroneous.

SUMMARY OF EVIDENCE

The following is a brief summary of the evidence submitted on behalf of appellant

Mr. Sven Rolfsen, Jr., a graduate mechanical engineer, testified (App. 21) that he modified a commercial one-cylinder marine engine so that it could be operated in accordance with appellant's method, that he assisted in the testing of the modified engine in the mechanical engineering laboratory of the University of Rochester, and that improved efficiency of operation was obtained in comparison with the same engine operated by the conventional method with absence of "knocking" even with low octane fuels such as kerosene.

Mr. Corwin Rickard, instructor in engineering at the University of Rochester, testified (App. 26) as to the engine tests at the University of Rochester, and gave further details as to the increased efficiency and improved utilization of low grade fuels by the method of the invention.

Dr. Lewis Conta, professor of mechanical engineering at the University of Rochester, (App. 32) corroborated the testimony of Rolfsen and Rickard as to the engine tests. Dr. Conta explained in detail with reference to charts (Plaintiff's Exhibits 2-7), the principles of operation of appellant's method and the distinctions in principle of operation from the three prior patents principally relied on by appellee.

Mr. Alanson P. Brush (App. 68), former chief engineer of Cadillac, now an outstanding consulting engineer in the automobile industry with nearly fifty years of experience in the designing of automobiles and automobile engines, testified in detail as to the practical value of appellant's invention, and pointed out the distinctions between appellant's method and the disclosures of the prior patents. Brush also pointed out explicitly the erroneous interpretations and conclusions of the Board of Appeals.

THE BACKGROUND OF THE INVENTION

Conventional internal combustion engines are of two general types; the Otto engine, which employs an electrical spark ignition, and the Diesel engine, which employs the heat of compression for ignition. Both the spark-ignition and the compression-ignition engines operate on the principle of burning fuel with air in order to expand the air within the cylinder-combustion-space and so develop pressure on the piston which pressure is transmitted through a connecting rod to the crank shaft. The automobile engine is a typical example of spark-ignition engines; the engine in a Diesel locomotive is a good example of the application of the Diesel principle. Both engines may be made to operate on either what is known as 2-cycle or the 4-cycle operation. In the 2-cycle engine there is one combustion stroke for each revolution of the crank shaft. In the 4-cycle engine there is one combustion stroke for every two revolutions of the crank shaft. The average ignition engine is designed to idle at 250 R. P. M. (revolutions per minute) and develop its maximum horsepower at from 3,000 to 5,000 R. P. M. depending on the design of the engine and the purpose for which it is to be used.

In comparing the Diesel (compression ignition), the Otto (spark ignition) and the Broderson (spark ignition) engines, we will confine our comparisons to the four-cycle operation which requires two revolutions of the crank shaft, utilized as follows; induction stroke, compression stroke, combustion stroke (sometimes called power stroke) and exhaust stroke.

In the 4-cycle Diesel engine, starting with the induction stroke (piston moving from top dead center to bottom dead center), pure air is drawn into the cylinder through the open intake valve. The compression stroke is that period completing the first revolution of the crank shaft which returns the piston to top dead center, compressing the air which is trapped in the combustion space. In order to generate sufficient heat it is necessary for the Diesel engine to employ very high piston compression, generally 400 to 500 pounds. In other words, the full volume of air inducted must be crowded into a relatively small combustion space thereby generating sufficiently high temperatures, by the compression of the air, to cause any fuel introduced into this heated air to ignite spontaneously. It is common practice to start this injection slightly before top dead center. The higher the speed, the earlier the introduction of the fuel is started to allow time for combustion. Injection of this fuel continues into the combustion stroke, (the downward stroke of the piston on the second revolution of the crank shaft.) At full power, injection continues throughout a large portion of the combustion stroke, new fuel entering and burning as the earlier fuel injected is expended. Upon reaching the bottom of the stroke, the exhaust valve opens and the crank shaft, completing its second revolution of the cycle, returns the piston to top dead center forcing the spent exhaust gases through the exhaust valve, completing the cycle.

The 4-cycle Otto engine resembles the Diesel in that it also employs intake stroke, compression stroke, combustion stroke and exhaust stroke. The great difference between the Otto and the Diesel engines is due to the fact that more highly combustible fuel is required in the Otto engine in order that it may be easily vaporized when added to the air, by means of a carburetor through which all air passes before entering the cylinder on the intake stroke. This early introduction of fuel to the intake air makes possible a gaseous mixture of air and fuel which is homogeneous and, if maintained in the optimum proportions of 15 pounds of air to 1 part of fuel and compressed to about 100 pounds piston compression, this homogeneous mixture will provide so rapid a combustion that it is frequently referred to as an ''explosion''.

The use of this term; namely, ''explosion'', is strictly incorrect for the following reasons. If the spark-ignition engine were designed to employ a piston compression of 400 to 500 pounds, as in the Diesel engine, this optimum rapidly burning homogeneous mixture would explode from the heat of compression in the early part of the compression stroke. This early explosion would break the engine or drive the piston back, reversing the direction of the crank shaft. When a spark-ignition engine is operating at 1,000 R. P. M., one revolution is completed in .01 seconds. The combustion stroke requires only ½ crank shaft revolution, or, .005 second. Research discloses that an optimum homogeneous mixture will complete its combustion within 5° to 30° of the 360° of the compression and combustion strokes. This rapid combustion, unlike the Diesel combustion, will cause a rise of the compression within the combustion space from the original 100 pound piston compression to approximately 450 pounds combustion compression. The air, which is part of the homogeneous mixture provides the oxygen to support combustion while expanding from the heat of combustion, thereby forcing the piston downward on the combustion or power stroke. Completing the second revolution of the crank shaft the piston is returned to top dead center, forcing the expended charge out of the exhaust valve. The disadvantage of the Otto spark-ignition engine, wherein all of the fuel is added on the intake stroke, lies in the fact that it requires something approaching an optimum mixture (15 parts of air to 1 of fuel) in order to be ignited by a spark. Therefore, as less power is required of the engine, a lesser amount of air must be allowed to enter the cylinder for compression in the combustion space in order to retain a mixture approaching the optimum or ignitable mixture. This is known as "throttling" the engine. When the amount of air is reduced by throttling, it becomes impossible to maintain the 100 pound piston compression inasmuch as the volume of the cylinder and combustion space remains constant; therefore, a reduced volume of air admitted will not compress to the same 100 pounds which is possible when a full volume of air is admitted. As a result, the heat of piston compression is reduced, requiring a richer mixture, such as 12 parts of air to 1 part of fuel, at a no load condition; the richer mixture being more readily ignitable by a spark at the lower compression temperature. Everyone has experienced the need of supplying a very rich mixture by choking the engine prior to such time as the combustion space has become heated.

The principal limitation to obtaining greater fuel economy in the Otto engine is its inability to ignite its fuel charge except within a relatively small range of air to fuel proportions. In order to maintain a constantly optimum mixture to insure ignition under all conditions of operation, the Otto engine must reduce the volume of air consumed at least in proportion to the reduction of fuel consumed. In other words, burning 50% of fuel and 50% of air at one-half the compression will not give 50% of the power that would be obtainable if it were possible in the Otto engine to ignite and burn 50% of the fuel and 100% of the air at the full chosen compression for the engine (App. 81).

APPELLANT'S INVENTION

Appellant's invention makes it possible to utilize and obtain the advantages of both the complete combustion of the Otto engine and the constant full air charge of the Diesel type of engine. This results in a remarkable increase in efficiency in engine operation.

Appellant's engine employs the 4-cycle principle requiring two revolutions of the crank shaft to complete the cycle as described for the 4-cycle Diesel engine and the 4-cycle Otto engine. The Diesel engine injects fuel into high compression pressures and, therefore, must employ injection pumps developing very high pressure. Extreme precision in its manufacture is necessary and costly. The Broderson engine injects fuel into the cycle on the intake stroke and the early part of the compression stroke at which time there is a partial vacuum on the intake stroke and very little pressure in the early part of the compression stroke making possible the use of a greatly simplified low-cost injector mechanism. Like the Diesel compression ignition engine, the Broderson engine does not throttle the incoming air; it employs a substantially constant volume of air under all conditions of operation. It differs from the Diesel in the fact that it is designed to operate with spark ignition and high volatile fuels at compression ratios more comparable to the Otto engine. It differs from the Otto engine in the fact that it is able to operate without reducing or throttling the air when reducing the fuel to operate at low or part load demand. This is possible because of the method employed to segregate and to maintain an ignitable mixture in the vicinity of the ignitor under all conditions of operation from low load to full load. (See Example 3, App. 131).

The Otto cycle engine, as pointed out, requires a richer fuel-to-air mixture when the air is throttled and the power demand is reduced. In the Broderson engine, as the power is reduced, the air remains substantially constant. Only the fuel admitted is reduced resulting in over-all leaner air-to-fuel mixtures than have heretofore been successfully ignited by spark. More complete combustion is obtained because of the excess air containing oxygen available to support the combustion at part load.

Broderson's spark ignition engine also differs from the Otto ignition engine in that for any given combustible fuel the Broderson engine can operate at higher compression ratios. The ability of the Broderson method to segregate and to vary at will the mixture ratio in the vicinity of the spark ignitor makes possible a combination at full power requirements wherein the overall mixture of the entire combustion space is the optimum mixture for maximum power but segregated prior to and at the time of ignition to provide an overly rich mixture in the vicinity of the spark ignitor and a non-optimum or lean mixture in the main combustion space where detonation would otherwise take place. If the optimum mixture were uniformly distributed throughout as it is in the Otto engine then detonation would occur. This condition is described in greater detail in the Broderson application under Example I, Full Load Operation (App. 128).

Appellant's method requires a particular construction of the combustion chamber, as specified in the claims. One form of such construction is clearly illustrated in the drawings which are part of the Broderson application (App. 146-147). Referring to Figs. 1 and 2, the numeral 1 represents the walls providing a cylinder within which is the reciprocating piston 2 of a four-cycle internal combustion engine. The numeral 3 indicates an offset wall which, together with the cylinder head 4, provides an auxiliary combustion zone or chamber 5. The main combustion chamber is indicated by the numeral 6 and comprises the space between the top of the piston head and the overlying portion of the cylinder head 4.

In the auxiliary chamber 5 is located an intake valve 7, a spark plug or igniter 9, and fuel injector 10. The exhaust valve 8 is positioned in the cylinder head over the piston. The spark plug or igniter 9 is timed to produce a spark in the auxiliary chamber by conventional ignition and timing mechanism. The intake valve 7 and the exhaust valve 8 will be opened and closed by conventional mechanism at times in which such valves normally open and close in the operation of Otto cycle engines as described previously herein under that heading. The injector 10 may be of commercial manufacture but a special timing and duration of operation is required to inject or force fuel into the auxiliary combustion chamber in accordance with the teachings of the invention. This timing is part of the method which is new with appellant.

It should be noted that the volume of the auxiliary chamber 5 is not greater than the volume of the main combustion chamber 6 when the piston is at top dead center position. In the use of appellant's method the volume of the auxiliary combustion chamber 5 can properly be from 10 to 50% of the total volume of the two combustion chambers 5 and 6. The two chambers are separated by a restriction or reduction which causes the throat-effect as seen in Fig. 1 of the drawing.

In the operation of the Broderson method, utilizing the structure just described in connection with Figs. 1 and 2, and assuming that the engine is operating under full load requirements, as the piston starts down on the intake stroke, the intake valve 7 is open, permitting unthrottled air to flow in through the auxiliary chamber, filling both it and the main combustion chamber. During the latter portion of the intake stroke the fuel injector will be so timed that injection of fuel will start and will continue for the remainder of the intake stroke and during a slight portion of the beginning of the compression stroke.

The ratio of total fuel to air will be approximately the optimum, which is about fifteen parts of air for one part of fuel by volume. The fuel which is injected into the auxiliary chamber during the intake stroke will be carried with the air into the main combustion chamber and will begin to mix or homogenize with that air. When the piston has gone to its lower limit or bottom dead center, the intake valve 7 will close and the piston will then travel upwardly and start to compress the air and fuel in both.

During the first part of this compression stroke, injection of fuel by the injector 10 has continued into the auxiliary chamber and such fuel will remain in that chamber because of the fact that compressed air-fuel mixture is being forced into the auxiliary chamber from the main chamber. By the time the compression stroke has been completed, and because of the fact that the fuel was injected during the intake stroke and early part of the compression stroke, the mixture in the main combustion chamber will be substantially homogenized and the mixture in the auxiliary combustion chamber will also be substantially homogenized. By reason of the timing of the fuel injector just described, the fuel-air mixture in the auxiliary combustion chamber will be richer than in the main combustion chamber.

Therefore, it is assured that the mixture in the auxiliary combustion chamber will be at the optimum ratio to permit ready ignition, and in this case of full load operation, the mixture in the main combustion chamber will be only a little leaner than in the auxiliary combustion chamber. Near the end of the compression stroke the spark plug will fire, readily igniting the mixture in the auxiliary combustion chamber, and the flame front will travel out into the main combustion chamber, causing the mixture there to ignite and causing it to expand and drive the piston down, which is the power stroke.

With the same structural set-up but by the novel method taught by appellant, it is possible to obtain remarkable efficiency with a part load operation. Let us assume that only one-half of the power which the engine can produce is required, it being understood that the accelerator, by which an operator controls the engine, controls the operation of the injector to vary the timing and duration of the injections of fuel to auxiliary chamber 5. Under such part load operation, on the intake stroke the piston moves down and draws a complete charge of air in through the open valve 7, and it is not until near the very end of the intake or induction stroke that the position of the accelerator causes the injector to inject fuel, or possibly even not until the start of the compression stroke. In such case very little fuel is drawn in through the auxiliary chamber and into the main combustion chamber. The required amount of fuel to insure an ignitable mixture in the auxiliary chamber is injected during the start of the compression stroke, and the piston rising causes the relatively pure air in the main chamber to be compressed, and of course, a portion of it will flow through the throat into and mix with and compress the air and fuel in the auxiliary chamber 5. The air and fuel in that chamber will be thoroughly admixed or homogenized because of the limited size of the auxiliary combustion chamber and because the fuel was injected at the start of the compression stroke and therefore had time to mix with the air. When the compression stroke is substantially completed the spark plug fires, the readily ignitable mixture present in the auxiliary chamber starts to burn and spreads out into the main chamber, and because combustion has started with an ignitable mixture, that combustion continues into the main chamber causing complete combustion of the fuel in the main chamber even though the mixture in the main chamber might be so lean that it could not by and of itself be ignited by the usual electric spark.

In this latter case the same degree of compression is present in the cylinder at the end of the compression stroke as exists during full load operation. Therefore, the heat of burning acts on that highly compressed mixture, which is mostly air, whereby greater expansion is obtained than is possible with the conventional engine. In a conventional engine, under part load condition, only a partial charge of air is drawn in so that the compression rate is not as high and therefore the possible expansion rate is not as great.

In the conventional automobile engine at lower than maximum power demand, the amount of fuel fed must be reduced, but this reduction can be continued only to a limited extent before the mixture becomes too lean to ignite. In conventional engines the amount of fuel entering the combustion chamber is automatically reduced by throttling the air because the amount of fuel sucked in by the incoming air is proportionate to the quantity of air.

By so throttling the mixture of air and fuel, the ratio between them is maintained within ignitable and operable limits. Throttling by decreasing the volume of air in the cylinder, however, reduces the efficiency of conversion of the fuel into heat energy and thus reduces the efficiency of conversion of the fuel into useful work, resulting in a waste of fuel and a loss in efficiency.

In appellant's method of operating an internal combustion engine, air is drawn into the combustion space substantially unthrottled under all conditions of operation, thereby providing a uniform degree of compression in the cylinder at the time of ignition at all degrees of power output. More efficient utilization of the combustion energy in the fuel is thereby obtained.

Another defect of the conventional automobile engine is that in operating under high compression ratios, it must use specially prepared or treated fuel if detonation is to be largely avoided. Even when such fuels are used detonation occurs under some conditions of operation and we have all heard that familiar knock when an automobile engine is accelerating. Detonation has been explained as being due to the exploding of the fuel-air mixture in the unburned mixture before the flame front reaches it. A flame front radiates heat outwardly from the point of ignition which heats and expands the mixture in advance of it until a point is reached where the remaining unburned mixture attains a state of high compression and high temperature sufficient to cause it to explode. This explosion is commonly referred to as a "knock", and when an engine "knocks", the efficiency, the power output, smoothness and quietness of operation are disadvantageously affected.

Appellant's new method of operating an internal combustion engine comprises admitting air into the combustion chambers of the engine and compressing the air within the combustion chambers, injecting into the auxiliary combustion chamber controlled charges of fuel increasing in amount with increasing power demand upon the engine. The fuel is injected during a controlled period of time near the end of the induction or intake stroke and the start of the compression stroke, effecting a differential distribution of the fuel between the auxiliary combustion chamber and the main combustion chamber to provide in said auxiliary chamber an ignitable fuel mixture under all conditions of power demand, while varying the amount of fuel in the main combustion chamber in accordance with power demands.

By using an auxiliary chamber of smaller size than the main combustion chamber, and by having a restriction between the two chambers, it is possible to effect a controlled segregation of the total fuel supply and fuel-air mixture between the auxiliary combustion chamber and the main combustion chamber, whereby the fuel-air mixture in the auxiliary chamber is readily ignitable and the fuel-air mixture in the main combustion chamber is lean and therefore, will not explode prematurely and the undesirable knocking does not occur.

One of appellant's witnesses at the trial was Alanson P. Brush, an independent expert, a consulting engineer of Detroit, Michigan. As clearly shown from his qualifications (App. 68-70), Mr. Brush is one of the best qualified men in the United States in the field of internal combustion engines. Starting around 1901 he supervised the design, methods of manufacture, and the testing of engines and transmissions being made for the then Olds Motor Works of Detroit. Subsequent to that work his company undertook the manufacture of an engine for a company which later became the Cadillac Automobile Company, and he designed and supervised the production methods, and production of the engines and transmissions for the first models of the Cadillac Company. Mr. Brush also designed for the Cadillac Company a four-cylinder engine, and after three or four years with his original company and Cadillac, became Chief Engineer of the Cadillac Company.

Mr. Brush later organized the company which was originally known as the Oakland Motor Car Company and which, after purchase by General Motors Company, became the Pontiac Division of General Motors. He was Vice-President and Chief Engineer of the Oakland Company and when it was taken over by General Motors he made his headquarters at Flint at the Buick Motor Company as consultant to all the then existing divisions of the General Motors Company. He supervised the design of the first overhead valve engine used by the Oakland Motor Company and designed features which are still in use in today's Chevrolet and Buick engines. In 1913 he resigned from his position with General Motors and since that time has maintained his own office doing general consulting work, principally in connection with the automotive industry and much of it with automobile engines.

During the past five or ten years, among his clients in the automotive industry, he has acted as consultant for the Ford Motor Company, Chrysler Motor Company, General Motors Company, Packard Motor Company, and the American LaFrance Fire Engine Company, Elmira, New York. For the last mentioned company he designed and supervised the introductory commercial production of twelve-cylinder engines which that company has been using since 1930.

Mr. Brush was asked whether with the Broderson method it was possible to obtain combustion where you had a relatively rich mixture in the auxiliary chamber and a very lean mixture in the main combustion space at the time of ignition and he stated (App. 76):

> "Certainly it is possible to have a mixture of any desired quality within the ignition range in the auxiliary chamber, and have any degree of leaner mixture desired in the main chamber down to substantially pure air."

After Mr. Brush had described the structure and method he was asked what particular value such structure and method had, and he stated (App. 78):

> "Well, without at the moment going into explanation, Your Honor, I will simply say this: that if we are to get adequate return in usable power by the burning of fuel in an internal combustion engine, to get the maximum results in an Otto cycle engine, for example, fuel must be burned so as to heat a mass of air which air has been compressed up to the 100 percent of the chosen compression for that engine. That is a condition that the Broderson mode of operation establishes by its modification of the Otto cycle engine.
>
> "In the engines we are now using in automobiles, other than Diesel or semi-Diesel, in the Otto cycle engine, which is practically the universal engine for passenger or pleasure cars, privately owned cars, and when you release the pressure of your foot on your accelerator, what you do actually, what you do is close a throttle * * * of the manifold between the engine and the carburetor and reduce both air and fuel amounts substantially alike.
>
> "So that let us say at a point where half as much fuel and half as much air is taken into the engine, the compression existing at the time of ignition and at top dead center will be only 50 percent of the compression in that engine running at the same speed with the throttle wide open.
>
> "Now, burning 50 percent of fuel and 50 percent of air with 50 percent of compression will by no means give 50 percent of push downward on the piston during the working stroke, Your Honor. The ability of the fuel, of the heat generated by the fuel in the mixture to produce mechanical force, to deliver power to the piston, is greatly affected by the amount of compression of the air being heated."

The value of the restriction between the two chambers in the Broderson method was discussed by Mr. Brush, and after he had explained that the mixture in the auxiliary chamber should be about 15 units of weight of air to 1 unit of weight of fuel he stated as follows (App. 79):

> "Now, if in the operation of the Broderson cycle, which I have described, if this fuel in the auxiliary chamber was eddied out and mixed with a total volume of air, the mixture would not ignite, it just would not burn, so for purposes of getting combustion promptly, Otto cycle combustion, that is combustion of widely varying compressions and constant volume, and if we want to get quick complete combustion we would need in the auxiliary chamber about a 15 to 1 mixture, and in place of the 50 pounds compression, the full 100 pounds compression in an engine designed for 100 pounds of full compression."

With respect to combustion, Mr. Brush stated (App. 80):

> "It doesn't take place only in the auxiliary chamber because when under the conditions I outlined, after ignition, then the flame propogation goes through the homogeneous mixture, and there is a rush of flame burning fuel and combined air out into the main combustion chamber. We no longer care about the segregation there.
>
> "The transition zone has served the purpose of giving us the right mixture for ignition. After ignition is established, heat is being generated, pressure and temperature are rising, and we want this restricted opening—it has to be large enough so that burning fuel and air can rush out into the mass of pure air in the main combustion chamber and heat all the air substantially alike."

Mr. Brush further stated (App. 80-81):

> "I might summarize, I think, Your Honor, that the problem of Broderson to increase the economy of the Otto cycle engine at lower power outputs hangs on this proposition: It must establish a means and the method by which the Otto cycle burning can be accomplished with a reduced amount of fuel and unreduced amount of air, and that means that at the point of ignition there must always be the something nearer what I call the optimum burning mixture because the Otto cycle requires very rapid combustion at widely varying pressures with little variation of volume dur-

> ing the early part of the combustion. In that sense it is different from the Diesel cycle, which I won't go into unless Your Honor wishes it."

After further testimony as to the reduction of fuel in the Broderson cycle, Mr. Brush testified as follows (App. 81):

> "Q Without going again into any of the reasoning behind it, Mr. Brush, is that of any practical value in connection with fuel savings or fuel consumption?
> "A Indeed it is. As I previously pointed out, the unmodified Otto cycle, when it is burning half the amount of fuel required to give full power is giving much less than half of the full power.
> "With the Broderson cycle operating, the burning of half the amount of fuel will give something more than half the full power output if that half amount of fuel is burned in accordance with the requirement of the Otto cycle in an unreduced amount of air."

The value of the invention of plaintiff and its advantages will be discussed further in connection with the testimony of other witnesses and in connection with the Broderson test engine.

THE BRODERSON TEST ENGINE

In order to make a comparison between appellant's engine and method of operation and a conventional Otto cycle engine, a conventional engine was secured and was modified by the installation of a head which would provide for the Broderson auxiliary combustion chamber and main combustion chamber (App. 22-23). It was further modified with respect to the valve and fuel injection system as taught by appellant, and that work was done by Mr. Sven Rolfsen, Jr., a mechanical engineer in the employment of appellant.

The tests were conducted in the laboratories of the University of Rochester after the final rejection of the claims by the Board of Appeals and the results of the tests, which information was not available at the time of the Patent Office proceedings, clearly show the advantages of the invention. At the trial Mr. Rolfsen testified as follows (App. 24-25):

> "We operated this engine with an injection system and also with a carburetor, making it a conventional induction type engine as in your automobile so we could compare the two systems.
>
> "We were able to run tests at all readings, full load right on down to no load, taking our readings off conventional testing equipment.
>
> * * * *
>
> "Q What did you observe as to the efficiency between the operation with the injection system and the operation of that same engine without the injection system and operated with the use of carburetion. What did you observe?
>
> "A Operating the engine as an injection engine, using the Broderson method, we had excellent results. It showed an increase in efficiency. The heat of the exhaust gases was considerably lower.
>
> "In relation to detonation, we experienced no detonation at all, even though we used Diesel fuel, kerosene, and very low octane gasoline.
>
> "However, operating under the same conditions as an induction engine, or carburetor engine, we had a terrific amount of detonation, so much so that we had to stop the engine for fear of destroying it.
>
> "The efficiency was several percent lower. Exhaust temperatures were approximately 400 degrees higher."

Mr. Rickard, the holder of degrees of Bachelor of Science and Master of Science in engineering, and an instructor in the Division of Engineering of the University of Rochester, testified as to studies of the Broderson test engine based upon tests made by him from approximately the middle of September, 1948, until the end of February, 1949. He testified (App. 30-32):

(a) that he observed that in making a comparative study between the Broderson method of operating an internal combustion engine and the normal conventional type of operation as in the automobile engine, under varied loads and under both methods of operation, there was a considerable increase in thermal efficiency for the Broderson method of operation over that of the conventional operation;
(b) that there was an increase in the degree to which the engine utilized all the energy available in the fuel;
(c) that with the Broderson method the engine was much more resistant to detonation than operating under the conventional method; and
(d) that they could operate under the Broderson method with poor quality fuels substantially without detonation and that upon switching over to the conventional method of operation, they had very violent detonation.

Another of appellant's witnesses was Dr. Lewis Conta, an independent expert, who is at present Professor of Mechanical Engineering at the University of Rochester and Chairman of the University's Engineering Division, and who has an unimpeachable background in connection with study, teaching and research in internal combustion engines. His background includes the writing of a thesis in 1935 on gasoline octane numbers and engine performance; serving as an instructor in engineering at the University of Rochester in thermodynamics, power laboratory, and internal combustion engines; and instructor and assistant professor at Cornell University, including teaching in the mechanical laboratory, experiments on fuel, heat engines, fuel flow and related subjects. During the war years, in a Navy-established school of Diesel Engineering at Cornell, he was first in charge of the fuel injection and engine control laboratory and later in charge of instruction in the entire Diesel engine course. After the war for several years he was research engineer for the Air Reduction Research Company of New Jersey, and recently he was engaged in an extensive survey of combustion engines for the National Research Council (App. 33-34).

Dr. Conta testified with respect to the test engine that he observed:

> (a) that the Broderson method was very advantageous over the conventional carburetor method with respect to detonation (App. 61);
> (b) that at any condition less than full load, the economy of the Broderson method of operation was substantially better than that for the carburetor operation (App. 61);
> (c) that such increase in economy would result in considerable fuel savings under the load conditions which are most commonly experienced in most automotive type engines (App. 61); and
> (d) that a poorer grade of fuel could be used by the Broderson method (App. 61).

The conclusion that must be drawn from the testimony of witnesses as to the Broderson test engine is that appellant invented a method of engine operation that is far superior to the present-day method. The advantages enumerated by the witnesses are of vast importance.

In its decision on request for reconsideration, (App. 172), 1947, the Board of Appeals stated:

> "The record before us does not establish that the method disclosed in the application on appeal can maintain high efficiencies at low power demands to an extent not attainable by the methods disclosed in the prior art."

The testimony of Mr. Rolfsen, Mr. Rickard and Dr. Conta proves that the test engine utilizing the Broderson method maintained high efficiencies at lower power demands to an extent not attainable by conventional methods of operation. That evidence was not before the Patent Office as the test engine had not been constructed and tried at that time and the testimony of the witnesses in this trial stands unrefuted.

It is to be noted, however, that appellant has not made any claim that his method of operation would maintain as high or higher efficiencies as engines operating under the Diesel principle. Appellant's invention is not directed to engines of that type but to a new method of improving the economy of operation of four-cycle, spark-ignited engines. What the efficiency of the Mock engine would be is not known, as no operation of an engine such as described in the Mock patent is known.

The Board's implication that appellant was required to prove higher efficiencies than any of the engines of the prior art was unrealistic and unsound.

CHARTS ILLUSTRATING THE BRODERSON INVENTION

At the trial appellant, through Dr. Conta, introduced a series of three charts (plaintiff's Exhibits Nos. 2, 3 and 4, which are included in the separately bound file of exhibits) which illustrate an application of the Broderson invention. The charts are directed to the comparative volumes of the auxiliary and main combustion chambers, the time of the period of injection of fuel under varying load conditions and the visual illustration of the fuel mixtures in the two chambers. The charts are based upon appellant's application for patent (App. 120). For example, in the application it is specified that the volume of the auxiliary combustion chamber shall not substantially exceed the volume of the main combustion chamber at top center of the piston and shall be preferably from 10% to 50% of the volume of the total combustion space at top center position of the piston.

The specific example in the patent application on which the chart (plaintiff's Exhibit No. 2) is based is Example No. 3 (App. 131). In that example it is stated,

> "this requires that the auxiliary combustion zone be

> one-fifth the total volume of the combustion chamber with piston at top dead center."

In the chart the auxiliary combustion chamber is shown as having 20% or one-fifth of the total volume. The application also states that,

> "the minimum fuel required for idling is contained entirely within the auxiliary combustion zone as a 15 to 1 air-fuel mixture at the time of ignition."

The application also points out that under the minimum load or idling conditions the fuel is introduced into the auxiliary combustion zone on the compression stroke. All of these requirements are followed in the chart.

In the chart (plaintiff's Exhibit No. 2), the series of drawings across the bottom represent the piston, the cylinder and the condition in the main and auxiliary chambers in several positions of the cycle (App. 36). The horizontal row of illustrations across the center of the chart are illustrative cross-sectional views of the two chambers looking down on the top of the views across the bottom row.

In the top portion of the chart is an illustration that looks like a roadway or path; the upper portion of this roadway or path has to do with the main chamber and the lower portion has to do with the auxiliary chamber.

Referring to the series of drawings pictured across the bottom of the chart, the second drawing from the left illustrates the piston going downwardly during the intake stroke. The intake valve at the top of the auxiliary chamber is open, permitting a full charge of air (indicated by the arrows and the green color) to be drawn into both the main and the auxiliary chamber. The third figure from the left illustrates the condition at or just after the bottom dead center position where the piston is going to start on the upward or compression stroke. At this time both chambers are completely filled with air and fuel injection is started into the auxiliary chamber. The blue coloring indicates the beginning of fuel injection. The beginning and extent of fuel injection is shown in the upper portion of the chart in what might be called the sidewalk which is located just below the path representing the auxiliary chamber. That sidewalk is colored blue starting at the bottom dead center (or BDC) and the injection as shown continues through about 25° (App. 37).

As the piston continues upwardly on its compression stroke, as shown at the bottom in the fourth figure from the left, the piston is forcing air ahead of it and compresses it, and substantially all of the fuel which has been injected into the auxiliary chamber remains there due to the compression. The last figure at the bottom right of the chart shows the condition at the time of ignition or firing, and at that time,

> ''the spark plug fires igniting the uniform homogeneous mixture which is present only in the auxiliary chamber, and the main chamber still contains only air.
>
> ''This represents conditions at very light load, that only enough fuel is injected to turn the engine over against its own resistance or against a very slight load, and that small amount of fuel must be concentrated with a small amount of air so that the mixture will be rich enough to permit ignition.''

The next chart discussed by Dr. Conta was plaintiff's Exhibit No. 3 which is based upon Example 4 of the patent application (App. 132). The condition illustrated by this chart and example is that of an intermediate or part load operating condition, that is, the engine is required to produce some power, it is not just idling, but it does not require the full power output required for a very heavy or full load. The only essential difference between plaintiff's Exhibit 3 and plaintiff's Exhibit 2 is that the starting of the period of injection of fuel has been advanced so that instead of commencing at bottom dead center or at the start of the compression stroke, the fuel injection starts at approximately 45° before bottom dead center during the intake stroke, and the injection of fuel is continuous during the rest of the intake stroke and for approximately 15° of the return or compression stroke, as shown and as testified by Dr. Conta (App. 39-40).

As illustrated in the bottom figures of Chart 3 where the fuel injection starts during the intake stroke, the fuel being injected at that time is carried with the air being drawn into the main combustion chamber. The fuel which is injected after the intake valve closes at bottom dead center remains in the auxiliary chamber and is mixed with the air present in that chamber. During the compression stroke the piston rises and compresses the air in the main chamber and forces a part of that air-fuel mixture back into the auxiliary chamber while compressing the mixture therein contained. The result obtained as illustrated by the chart is that the mixture in the auxiliary chamber is richer than in the main chamber. The mixture in the auxiliary chamber would have an air-fuel ratio in the readily combustible range, while the mixture in the main chamber is leaner so that it would not burn of itself, but will burn when the flame of combustion from the auxiliary chamber flashes into the main chamber and raises its temperature and pressure. Just prior to or at the time of ignition, in Dr. Conta's opinion, the mixture in the auxiliary chamber would be substantially homogeneous and the mixture in the main combustion chamber would also be substantially homogeneous (App. 40).

The chart, plaintiff's Exhibit 4, illustrates the full load method of operation under appellant's invention and is based upon Example 5 of the application (App. 132-133).

In plaintiff's Exhibit 4, the engine is requiring the use of its full capacity and in order to bear the increased load additional fuel is required. In order to provide that additional fuel the injection period must be lengthened. The beginning of the injection is at approximately 75° before bottom dead center so that more fuel is injected during the suction or intake stroke. Such fuel mixes intimately with the air in the main chamber being carried there by the entering air stream, but a reduced amount of injection continues beyond bottom dead center and the fuel so injected remains in the auxiliary chamber, resulting in a mixture slightly richer than in the main chamber. The mixture in the auxiliary chamber at the time of ignition is substantially homogeneous and the mixture in the main chamber at that time is also substantially homogeneous (App. 40-41).

In each of the cases illustrated in plaintiff's Exhibits 2, 3 and 4, at the time of ignition the mixture in the auxiliary chamber was an ingnitable one and of substantially the same degree of richness, whereas the degree of richness of mixture in the main combustion space varied from substantially pure air in Exhibit 2, to a mixture practically as rich as in the auxiliary chamber as shown in Exhibit 4. The conditions that made these differences possible were stated by Dr. Conta as follows (App. 42):

> "A Well, first, the fact that the injection into the auxiliary chamber occurs partly in the suction and partly in compression stroke, so that the portion of fuel injected during the intake stroke will mix thoroughly with the entering air, and that part which is injected in the compression stroke will be confined to the auxiliary chamber, and in addition, in order to get the substantially homogeneous mixture, sufficient time must be allowed for mixing and diffusion to take place. Therefore, that fuel must be in early, well before ignition.
>
> "Q Has the size of these two combustion chambers anything to do with this?
>
> "A They do in this respect: In order for the en-

> gine to run at all, an ignitable mixture must be present at the spark plug. If the mixture becomes excessively lean, ignition will not occur.
>
> "In order to have the small amount of fuel necessary to run the engine at no load, a mixture with only sufficient air to form a combustible mixture, the auxiliary chamber must be reasonably small. If that chamber is large, the small amount of fuel necessary will result in a lean mixture which will not ignite.
>
> "Q Is there any type of restriction or constriction or anything of that nature between the two chambers necessary or desirable to assist in achieving the result that has been illustrated?
>
> "A Yes, there is.
>
> "Q What is the purpose or function of the restriction, such as shown between those chambers?
>
> "A Restrictions for the purpose of forming two chambers in each of which a uniform homogeneous mixture can be obtained."

Dr. Conta, in discussing the desirability of having a homogeneous mixture, stated as follows (App. 43):

> "A A homogeneous mixture will fire more completely than a non-homogeneous mixture, with resulting higher efficiency. Furthermore, complete utilization of the air in an engine is only possible if the mixture is homogeneous.
>
> "To put it another way: If the mixture is not homogeneous, then there will be molecules of fuel and molecules of oxygen which will not meet and will not combine, and there will be un-combined oxygen and fuel."

The purpose of the charts was to show visually the time and place of fuel injection, the extent of duration of the fuel injection, and the condition of the air-fuel mixtures in the combustion chambers during various portions of the cycle. The charts are also of value for comparison with similar charts of the Mock and Werner patent constructions and methods of operation, which charts will be discussed later.

MOCK PATENT, NO. 2,142,280

The first of the three prior art patents which counsel for appellee stated at the trial would be relied upon by appellee is the Mock patent, No. 2,142,280 (App. 97). The Mock patent is directed to an internal combustion engine employing spark ignition and operating in the combustion pressure range of the Otto cycle. This patent discloses injection of fuel, prior to ignition, into a combustion space connected to the cylinder proper. The uncontroverted testimony of the experts at the trial clearly shows that the teachings of this patent have been erroneously interpreted by the Patent Office tribunals and the District Court.

In the Mock patent, it is important to note that the location of the piston at top dead center position is shown only in Figures 4 and 6. In Figures 1, 2 and 3 the piston is on its way up or down in the cylinder and is not at its uppermost position. The position of the piston in Mock is of importance to Mock in order to accomplish the results which Mock desires to obtain, and the positon of that piston is important to plaintiff because it clearly shows that Mock has only one combustion chamber which is of relatively large size and that is the antithesis of planitiff's structure wherein an auxiliary chamber of small size in comparison to a main combustion chamber of large size is provided.

In Mock the piston is designated with the numeral 9. At the top of the cylinder there is provided an exhaust valve 10 and an inlet valve 11. The heart shaped combustion chamber is designated with the numeral 15 and in that chamber are located two spark plugs or igniters 20 and 21. An injector, numeral 18, is positioned as shown between the two spark plugs. In Figures 1, 2, 3 and 4, the combustion chamber 15 of Mock is never completely cleared of burned gases due to the location of the intake and exhaust valves. In a modification of the Mock invention shown in Figures 6 and 7 it would appear that the intake and exhaust valves are located in the combustion chamber 15 and in such case and under some circumstances that chamber would be airswept.

In the operation of the Mock device of Figures 1 through 4, fuel is injected through the injection nozzle 18 into the chamber 15 early in the cycle. That is, during the late exhaust or early intake strokes of the piston (Mock patent, page 2, column 1, lines 68-72, App. 99). It is, of course, apparent that fuel could not be injected in the structure of Figure 6 during the exhaust stroke as it would be forced out into the atmosphere past the exhaust valve with the exhausting burned gases. Therefore, as to Figure 6 fuel injection would have to take place later.

The fuel injected into the combustion chamber 15 of Figure 1 is held there by the piston raising and forcing air into the chamber and the result is a mixture which varies in richness from the injector out toward the entrance 16 to the cylinder. (App. 46) The space above the piston at top dead center is negligible; therefore, the entire mixture that is to be ignited, burned and expanded is contained in the chamber 15 and that mixture is not a homogeneous mixture according to Dr. Conta. The two spark plugs are used with the hope that an ignitable mixture will be in the vicinity of one of them (App. 47). There is no possible way in which Mock can have a mixture of one degree of richness in the chamber 15 and a mixture of a different degree of richness for any useful purpose in the cylinder in the small space above the piston 9 at its top dead center position (App. 47). In considering this statement of the witness, the court's attention is invited particularly to Figure 4. Mock has no way in which he could possibly vary the richness of mixtures in two chambers, as Dr. Conta described could be done in connection with the Broderson method (App. 47).

One intended method of operation of the Mock device is shown in the chart, plaintiff's Exhibit 5. In that chart it will be noticed in the curve across the top thereof, that no division into auxiliary chamber and main chamber is made for the reason that Mock shows and describes only one combustion chamber. The injection of fuel of necessity is into that one combustion chamber and such injection is shown as taking place by the blue coloring in the portion above the curve of the combustion chamber during the end of the exhaust stroke and just prior to the intake stroke. The four figures at the bottom show, starting from left to right, that all of the air or mixture which gets into the cylinder is forced up into the single combustion chamber, as is shown in the figure at the lower righthand side which is the only figure illustrating the top dead center position.

That is the condition at the time ignition becomes effective and it is plainly seen that under such condition it would be impossible to vary the richness or leanness of mixtures in two different chambers to achieve the efficiency of the Broderson operation at all loads less than full load.

A variation of the Mock method of operation is shown in the chart, plaintiff's Exhibit 6, wherein as taught by Mock a portion of the fuel is injected during the intake stroke and the remainder of the fuel injected near the end of the compression stroke and just prior to ignition. But again we have the same single combustion chamber, and the inability in the Mock structure or method of obtaining a rich ignitable mixture in a relatively small chamber and a leaner mixture in a large combustion chamber to obtain the efficiency obtainable by Broderson at less than full load conditions.

According to Dr. Conta, stratification in the sense of Broderson is not possible to obtain with the structure and method of Mock. Dr. Conta stated (App. 49):

> "Broderson's concept is stratification in the two homogeneous mixtures separated from one another.
> "In Mock, there is no possible provision for two homogeneous mixtures but rather for one non-homogeneous in a single chamber."

It is very clear from a consideration of Figures 4 and 6 of Mock that the so-called auxiliary combustion space is his only combustion space at the time of ignition. The insignificant space above the piston at this time, provided merely for mechanical clearance between the top of the piston and the cylinder head, does not in any way lessen the truth of this statement.

The following is a summary of references to the statements of the expert witnesses and of the Mock patent itself, clearly proving the erroneous interpretation which the Patent Office tribunals and the District Court have placed on this patent:

1. The Mock patent has only one combustion space:

   Conta (App. 45-46)
   Brush (App. 82-86)
   Mock patent (App. 97, Fig. 6)

2. The Mock patent does not provide homogeneous fuel-air mixtures:

   Conta (App. 51)
   Brush (App. 83)
   Mock patent (App. 98, left column, lines 31-32)

3. The Mock patent contains no suggestion of appellant's new method of operation:

   Conta (App. 47-48)
   Brush (App. 86)

BRITISH PATENT, NO. 373,647

The second prior art patent which counsel for the appellee stated would be relied upon is the British patent, No. 373,647 (App. 114). This patent is *not* directed to a method of operating an internal combustion engine. It is directed to an improvement in the operation of a *Diesel* engine. Following the Diesel compression-ignition principle as herein before described this engine employs very high compression pressure; approximately 400 to 500 pounds. Any fuel introduced to this engine on the intake stroke, or the early part of the compression stroke, would explode far in advance of the desired time for combustion to take place. Such explosion would either break the engine, or cause the piston to reverse its direction which would make the engine inoperative. It is well known that very high compression produces a very high temperature in the air compressed. No one conversant with internal combustion engines would attempt to operate an engine as disclosed by this British patent, using a homogeneous charge introduced or injected on the intake and early part of compression stroke as taught by Broderson (App. 92-93).

Fuel injected into the cylinder in accordance with the Diesel principle is notoriously difficult to ignite, especially when cold. Even after ignition takes place globules of fuel fail to contact air and therefore are not burned. The result is incomplete combustion and a smoky exhaust with offensive odor. The British patent is directed to retaining the heat of previous combustion cycles to aid in breaking down rapidly globules of fuel and producing more complete combustion. The ante-chamber described is designed to have a minimum of contact with the cooling walls of the cylinder head in order to retain its heat. (App. 116—Lines 104-104ff). Construction of the engine disclosed in the British patent provides no means of sweeping the ante-chamber with fresh air. The patent makes no mention of timing of injection other than that it follows the original Diesel practice in which the beginning of injection is at the point where ignition is desired to take place and the injection continues on into the combustion stroke, the new fuel burning as it enters the combustion space. There is no similarity in this patent to Broderson method as is clearly pointed out in the uncontroverted testimony of Doctor Conta.

Dr. Conta testified as follows (App. 55):

> "First, Dr. Conta, in your opinion, does this British patent teach or suggest the method of the Broderson patent application?
> "A No, in my opinion, it does not.
> "Q Now, assuming that it would be possible in some way to join or combine this British patent with the Mock patent, 2,142,280, which you have already discussed, in your opinion, would the combination of those two patents either teach or suggest the Broderson method?
> "A In my opinion, no combination of these two patents would suggest the Broderson teachings."

WERNER PATENT, NO. 1,616,157

The third of the three patents referred to by counsel for appellee as representing the best of the prior art is the Werner patent, No. 1,616,157 (App. 101). The drawing of the structure of the Werner patent was described in detail by Dr. Conta (App. 55-59). The Werner structure shows the usual piston, cylinder and valve mechanism, a combustion chamber R located above the piston and an ignition chamber or retort K. As shown in Figures 1 and 4 there is a spark plug S in retort K and an auxiliary fuel injector N′. The main fuel injector is N and it is located to inject or discharge fuel down into the combustion chamber R.

In the righthand portion of retort K is a valve 17 having a spring 18 and under certain types of usage that valve will be used to open a passageway which will draw fuel and air in through a carburetor designated with the letter M.

In the operation of Werner, fuel is introduced into K by the injection nozzle N′ as the piston approaches the top of its compression stroke. The mixture of fuel and air in K is ignited by the spark plug S and the flame passes out of the retort through the passageway 20. At the same time the regular fuel for power is being injected through the main injection nozzle N down into the main combustion chamber and that fuel is ignited by the blow torch action of the flame coming out of K through the opening 20. An analogy might be drawn between the operation of flame emanating from retort K and the operation of the pilot light on an ordinary domestic gas-fired hot water heater.

The Werner patent is directed to what might be termed a hybrid engine, partly Otto cycle, employing spark ignition; partly Diesel in that the main body of fuel is injected and burned during the combustion stroke. This is clearly stated in the Werner patent (App. 104, lines 9 to 15) as follows:

> "It is an object of the invention to provide an engine of the present character having a novel mechanism whereby fuel can be admitted to its combustion chamber at the time of, BEFORE AND AFTER INITIAL IGNITION——"

A comparable description of the Broderson method would read:

> "It is an object of the invention to provide an engine of the present character having a novel method of injection whereby fuel can be admitted to its combustion chamber at the time of, BEFORE OR AT BOTTOM DEAD CENTER OF THE INTAKE STROKE, CONTINUING INTO EARLY PART OF THE COMPRESSION STROKE."

Also in lines 47-51 (App. 104) Werner says:

> ". . . the variations in the output are then controlled by varying the amount of fuel burned at constant pressure without varying the amount burned in constant volume".

To restate Werner's objective in different words, Werner is endeavoring to burn fuel throughout a longer period of the combustion cycle by injecting his fuel before, during and *after* ignition takes place. It is true that fuel introduced to the retort or super-ignitor pocket by means of a carburetor would be a homogeneous mixture. It is equally true that fuel injected into this super-ignitor pocket will be non-homogeneous and therefore difficult to ignite by a spark when injected almost simultaneously but slightly before ignition. Irrespective of the condition of the charge in the super-ignitor pocket, at no time does Werner provide a homogeneous charge to the main combustion space. Werner relies on the fuel injected into the main combustion space for the main source of his power output. His auxiliary space heretofore referred to as the super-ignitor pocket can be likened to the primer in a cartridge. Recognizing the difficulty of igniting a non-homogeneous mixture, Werner's patent is directed to overcome the difficulties of igniting and rapidly burning a non-homogeneous fuel by providing a pre-combustion mixture, which, after ignition by a spark, will provide a flame of sufficient intensity to maintain combustion of the additional fuel not injected during the combustion stroke.

Appellant's Exhibit 7 is designed to diagrammatically represent the Werner combustion cycle. Only two-thirds of the cycle are shown. The exhaust stroke is omitted. On comparison of Exhibit 7 with Exhibits 2, 3 and 4, the extreme difference between Werner and Broderson method will be apparent.

Werner has two injection nozzles; one for the main combustion space and one for the super-ignitor space.

Broderson has one injection nozzle. Werner injects his super-ignitor fuel slightly before, almost simultaneously with the point of ignition. He injects his main combustion fuel slightly before ignition and continues injecting into the combustion stroke as does the Diesel engine. All of the fuel introduced by the Broderson method is injected either in the very beginning of the compression stroke for part load, or on the intake stroke continuing into the compression stroke, for full power. Fuel introduced in accordance with the Broderson method has ample time to mix with the air on the compression stroke and become a homogeneous mixture in both auxiliary and main combustion spaces and so provide a readily ignitable combustible mixture which, upon ignition, will cause a great increase in pressure of short duration within the combustion space. The Werner method is directed to provide a minimum of increase in pressure, but to maintain this pressure for the longest possible portion of the combustion or power stroke.

In the Werner method no fuel injected into the main combustion space ever enters the super-ignitor pocket. In the Broderson method, other than at minimum load, all fuel passes through the pre-combustion pocket into the main combustion space, some of the fuel from the main combustion space returns into the pre-combustion pocket during the compression stroke. This condition is mentioned to further emphasize the difference between the two engines.

In the Werner method there is no controlled stratification or segregation possible without using two separate sources of fuel supply to the combustion spaces (App. 93-134). Any difference in composition of the mixtures in Werner's main combustion space and his super-ignitor pocket is dependent upon the use of two injectors.

Broderson employs timing of injection and the duration of injection to supply fuel mixtures to two combustion spaces and maintains a readily ignitable mixture in one while varying the mixture ratio of the other (App. 94).

The resemblance of the Werner engine and the Broderson engine does not extend beyond the design of the combustion spaces of the two engines.

The method of operation for which Broderson is seeking a patent is totally different from the method described by Werner. Broderson application is for a patent covering a new method of operating an internal combustion engine.

Dr. Conta testified as follows (App. 59):

> "Q Now, Doctor, with respect to Werner, in your opinion, does Werner either teach or suggest the Broderson method of operation?
> "A In my opinion, the disclosures of Werner do not teach or suggest the method of Broderson."

THE FINDINGS OF FACT

The critical findings of fact of the District Court are findings numbered 4, 5 and 7 (App. 17-19) which are substantially identical with the holdings of the Board of Appeals. These findings are contrary to the uncontroverted testimony of the expert witnesses and are clearly erroneous in fact.

In finding No. 4, the Court said:

> "The patent to Mock discloses a four-cycle internal combustion engine having a main combustion chamber, formed between the top of the piston at its uppermost position and the bottom of the cylinder head, and an auxiliary combustion chamber communicating therewith through a restricted passage."

Mr. Brush, one of plaintiff's independent experts, testified with respect to whether or not the space above the piston in Mock was a combustion chamber, as follows (App. 82):

> "* * * the drawing shows clearly what we practice in commercial engines today, where you have a compression of a head, just clear of the compression of the cylinder head, just clear of the piston at top dead center, we call that simply the required the mechanical clearance for safe operation of the engine, and more than that, its vertical dimension, its thickness, so to speak, Your Honor, is so limited that it can in no sense be called a combustion chamber. It lacks both volume and it lacks form."

Brush further testified with respect to Mock, as follows (App. 82-83):

> "Q Because you have just been over the Broderson method, the result that Broderson obtains, I would like to ask you whether that same method and same result is, in your opinion, obtained in this Mock structure?
>
> "A It is not.
>
> "Q Is there anything comparable to it obtained by the Mock structure or method?
>
> "A It is my considered opinion that there is not.
>
> "Q Now, in Mock is it possible, Mr. Brush, to vary the richness or leanness of a fuel charge mixture in the main combustion chamber, to vary that with respect to another combustion chamber that is somewhat adjacent, so that we have two different areas of homogeneous mixtures varying in their richness?
>
> "A There is no such possibility shown in Mock, and perhaps the most obvious reason to a skilled mechanic is that there is but one combustion chamber provided.
>
> "Q In the one combustion chamber that is provided, Mr. Brush, what is your understanoding from the teaching of Mock as to whether or not there is a homogeneous mixture in that one combustion chamber?
>
> "A He does not—Mock does not even pretend to have a homogeneous mixture at the time of ignition."

The portion of the decision of the Board of Appeals terming the space above the piston "a main combustion chamber" was read to Brush and he was asked as a practical man, as a practical expert, whether Mock showed in the light of the teachings of Broderson a main combustion chamber and an auxiliary combustion chamber, as the Board of Appeals had stated in its decision, and his answer was (App. 84):

> "Mock does not."

The Court further stated in finding No. 4:

> "The only real difference between the method disclosed in the Mock patent and that expressed in the plaintiff's claims in suit resides in the structural limitation in the claims to the effect that the volume of the auxiliary combustion chamber does not exceed the volume of the main combustion chamber at top center position of the piston."

The statement in the opinion of the Board of Appeals to the effect that it is clear that all of the method steps recited in claim 1 are disclosed in Mock was read to Brush and portions of claim 1 of the plaintiff's application were read to Brush. His testimony clearly proving that the Board of Appeals was obviously incorrect is as follows (App. 85-86):

> "Q Now, the claim continues in this way: 'Supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine.'
> "Now, where in Mock, Mr. Brush can it be pointed out 'Supplying to the combustion chambers controlled charges of fuel varied in amount in relation to the power demand upon the engine'?
> "Can you point that out?
> "A I cannot.
> "Q Now, the next portion of the claim continues: 'Injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in

> amount in predetermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber.'
>
> "Can you find that in Mock, Mr. Brush?
>
> "A I cannot.
>
> "Q And the claim continues: 'And to provide in the auxiliary combustion chamber at the time of ignition an ignitable fuel mixture under all conditions of power demand irrespective of variation in composition of the fuel-air mixture obtained in the main combustion chamber.'
>
> "Do you find in Mock any ignitable fuel mixture in the auxiliary chamber, or this chamber 15, always ignitable irrespective of variation of composition of the fuel-air mixture obtained in the main combustion chamber?
>
> "A If Mock's single combustion chamber is called an auxiliary chamber, there is no main chamber. If it is recognized for what it is, the main chamber, there is no auxiliary chamber.
>
> "BY THE COURT:
>
> "Q As I understand your contention, in Mock there is only one combustion chamber?
>
> "A In the patent to Mock, Your Honor: When the piston is at upper dead center.
>
> "BY MR. BEAN:
>
> "Q On page 4 of its decision the Board stated as follows: 'It is clear therefore that all of the method steps recited in Claim 1 are disclosed in the Mock application and that the only feature whereby this claim may be said to differentiate from the Mock patent is in the structural limitation to the effect that the volume of the auxiliary chamber does not exceed the volume of the main combustion chamber at top center position of the piston.'
>
> "Now, is that statement, in your opinion, correct, Mr. Brush?
>
> "A That statement, in my opinion, is profoundly in error."

In finding No. 5 the Court said:

> "No invention is shown by plaintiff in applying the process disclosed in the Mock patent to an engine

> in which the auxiliary combustion chamber is not larger in volume than the main combustion chamber, particularly in view of British Patent, No. 373,647, and also of the Werner patent, each of which discloses a main combustion chamber and an auxiliary combustion chamber that are so related as to volume.

In its decision the Board of Appeals coupled the Mock disclosure, wherein the auxiliary combustion chamber 15 is much larger than the main combustion chamber (according to the Board of Appeals), with the British Patent 373,647, wherein a so-called auxiliary combustion chamber is not larger in volume than the main combustion chamber. After describing the British patent, which is directed to a Diesel type of engine, Brush was asked whether the heart-shaped combustion chamber of the Mock patent was considered by Mock to be of any importance, that is, the shape of the combustion chamber, and Brush testified (App. 88) in part, as follows:

> "That is, as far as the description given of his device by Mock, is one of his major objectives. What he is seeking to do is to prevent detonation, which is objectively any noise, which is objectively any strain, which is objectively any waste power, to prevent detonation by having a twin flame front."

Brush further testified as follows (App. 88-89):

> "Q In your opinion, Mr. Brush, as a practical man, would it be possible without interfering with the teachings of Mock to incorporate into Mock the structure of this British patent that we have just discussed?
>
> "A Well, you certainly could not incorporate the structure of the British patent that I assume the Patent Office referred to, namely, the part shown in Figure 3 and also part of that from G2 up to the line above.
>
> "Q That is on sheet 2 of the drawing?
>
> "A Figure 3. In Figure 2, or that shown in Figure 1 where that same part is shown installed in the engine.
>
> "Chamber F inside this member G is, I suppose, what the Patent Office referred to. That, of course, could not in Mock have its function as in the British

> patent, and I see no way in which it could have any useful function at all in Mock. Certainly, however, combined with Mock, that kind of chamber could not be by any stretch of the imagination the Broderson auxiliary chamber because, as I have already pointed out, Your Honor, the Broderson auxiliary chamber is air swept, all of the air, and in the figures we have referred to, all of the air going into the engine goes through the auxiliary chamber of each cylinder.
>
> "Q Now, Mr. Brush, if we assume that it were possible to combine this teaching structure of the British patent together with Mock, in your opinion, would that teach or suggest the Broderson construction or method that we have described?
>
> "A It would not."

It is evident from the foregoing that in the considered opinion of an extremely well-qualified, practical man who has spent more than forty years in designing and building and engineering work on internal combustion engines, he knows of no way wherein the teachings of Mock and the British patent can be combined and no way in which, if combined, they would teach or suggest the invention of Broderson.

In finding No. 7 the District Court said:

> "With respect to the four-cycle engine disclosed in the Werner patent, variation of the amount of fuel injected at the various parts of the cycle for the purpose of avoiding detonation is a mere matter of adjustment well within the scope of knowledge of the skilled mechanic.

The Board of Appeals in its opinion stated:

> "* * * we find the method recited in Claim 1 disclosed in the Werner patent so that the claim is unpatentable over that patent without the use of any auxiliary reference."

The statement just quoted was read to Brush at the trial and the following from Claim 1 of plaintiff's patent application was read:

> "* * * injecting into the auxiliary combustion chamber during the compression stroke of the piston controlled portions of said charges of fuel varied in

> amount in predtermined relation to the total quantity of fuel supplied to effect a controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber, * * *".

Brush was then asked, as follows:

> "Do you find that portion of the method of Claim 1 that I have just quoted either taught or suggested in the Werner construction or method?"

His answer was as follows:

> "It is not; no part of it." (App. 93)

He was then asked whether there was any controlled stratification in Werner and his answer was "No."

The principle of operation of the Werner patent is a hybrid principle but under all conditions it retains the typical feature of the Diesel cycle in that at least a portion of the fuel burns *as it enters the combustion chamber during a portion of the power stroke* with the inevitable result of incomplete combustion due to lack of opportunity for homogenization.

The wording of finding No. 7 also incorporates language from the decision of the Board of Appeals of May 26, 1947 (App. 168) reading as follows:

> "The variation of the amount of fuel injected at the various parts of the cycle for the purpose of avoiding detonation is considered a matter of adjustment and within the scope of knowledge of the skilled mechanic and we do not find claim 1 to distinguish from the prior art by reason of the effect of the recitation of the relation of the quantity of fuel charged at the various times in the cycle."

In order to clearly show how incorrect the foregoing statement is, it will be considered with respect to the prior patents relied upon by appellee whether a variation of the quantity of fuel, charged at various times in the cycle, could give the results obtained by appellant.

First, with respect to the Mock patent 2,142,280, regardless of when the fuel is injected or how much is injected, the result would still be some kind of a non-homogeneous mixture in the single combustion chamber 15 of Mock. There is no possible way in which any other result could be obtained, and that is true whether fuel injection takes place early in the cycle, late in the cycle, or at divided times in the cycle. At the time of ignition in Mock there is only one combustion chamber as appears clearly from plaintiff's Exhibits 5 and 6 in the last figure in the lower row. Mock can never obtain two different homogeneous mixtures in two chambers, which is essential to obtain the advantages secured by appellant.

As to the British patent 373,647, this is a Diesel engine and combustion starts when fuel injection begins. Therefore, the start of injection cannot be until the top dead center position of the piston is reached, or just prior to that time; otherwise the combustion or explosion would tend to knock the piston back down in the cylinder before the time it reached top dead center and was ready to swing over into the power stroke. This is an intolerable condition known as pre-ignition which produces engine backfiring. It would be absolutely impossible, with any variance in the time of injection, in the British method, to obtain two homogeneous mixtures of different degrees of richness in two different chambers, which is the very heart of the invention in this case.

In the Werner patent 1,616,157 the principal introduction of fuel for combustion to create power is through the utilization of the Diesel principle, that is, injection of fuel through the injector nozzle N directly into the main combustion chamber during the power stroke. When fuel injection starts, combustion starts, and therefore, such injection, as in the case of the British patent, cannot commence materially before the top dead center position of the piston is reached. With the principal fuel injection being through N into the main combustion chamber, and that injection continuing during a portion of the power cycle, it is absolutely impossible, by varying the time or amount of injection, to obtain the results obtained by appellant. Werner can never obtain two homogeneous mixtures stratified with respect to each other.

Besides defining that an ignitable fuel mixture is provided in the combustion chamber under all degrees of power demand, all of the claims in issue also define the volumetric ratio as between the main and auxiliary combustion chambers, without which the maintenance of ignitable mixtures and constant air charges at low power demand is impossible. It is this latter provision which provides a highly efficient mode of operation at low power demand which has never before been disclosed or proposed in spark-ignited internal combustion engines.

It is erroneous to try to synthesize appellant's invention by substituting the two combustion spaces of the British patent for the single combustion space of Mock. The operating conditions of these two engines are entirely different since the former is a Diesel type engine, where ignition is caused purely by the heat of air compression and extends through a major portion of the power stroke, while the latter is a conventional engine where ignition is caused by an electric spark and is substantially instantaneous. It is to this latter field of internal combustion engines that appellant's invention addresses itself.

Claims 3 through 6 and claim 8 are even more specific in defining over the prior art relied upon. These claims state that the constant air charges enter "at least in part through" the auxiliary combustion chamber. This is an important distinction because it insures that the auxiliary combustion chamber cannot form a "dead end" and trap burned gases from previous cycles. This danger is present in both Mock and the British patents, which reduces, if it does not destroy, the possibility of controlling the effective fuel-air ratio in their ignition spaces.

In summary, Dr. Conta and Mr. Brush, both of whom were familiar with the prior art relied upon and with the subject matter involved in this situation, that is, with both Otto cycle and Diesel cycle engines, testified that the prior art relied upon did not teach or suggest the Broderson invention. Mr. Brush testified that as to the prior art patents (in addition to Mock, British and Werner) cited in the answer in this case and offered in evidence, that he had read and was familiar with them; that he was in agreement with the position of the defendant that the three patents (Mock, British and Werner) discussed here are representative of the most pertinent prior art; that there are none of the other prior art patents taken by themselves which teach or suggest the Broderson method, as pointed out in the claims here in issue; and that there is no combination of those prior art patents which would either teach or show the Broderson invention (App. 93-94).

THE LAW AND AUTHORITIES

Appellant had the burden in the District Court of establishing by clear and convincing evidence that the decision of the Patent Office was erroneous. It is earnestly submitted that this burden has been fully met.

As this Court said in the very recent case of *Standard Oil Development Company* v. *Marzall*, 84 U. S. P. Q. 363; .... App. D. C. .... where there was substantial additional evidence before the District Court which was not before the Patent Office "we do not give to the decision of the Patent Office the weight to which it would be entitled if its rejection of the claims had been made on the same facts as were before the District Court."

Unfortunately, the opinion and findings of the District Court give this Court no assistance in the consideration of the highly pertinent, unequivocal and uncontroverted additional evidence presented on behalf of appellant. All that the District Court had to say about appellant's evidence in the opinion was:

> "Nor do I think that the testimony introduced at the trial in any way affects the conclusion reached by the Board of Appeals." (App. 16)

Substantially the same statement was made in finding of fact No. 9 (App. 19).

It is clear that if appellant is to have the independent judicial consideration of the critically important additional testimony adduced in his behalf which the statute was intended to afford him in this action, it must be obtained in this Court, and to that end the references to the testimony in the preceding portions of the brief have been made as specific and detailed as possible without extending the brief to undesirable length.

It is believed that this Court will find on consideration of the prior patents relied on by appellee, in the light of the uncontroverted additional testimony of appellant's witnesses, that appellant's new and valuable method of operating internal combustion engines is not suggested in any of these patents.

It is admitted by the District Court and the Board of Appeals that the structure essential to the carrying out of appellant's method as defined by the claims is not found in the principal reference, the Mock patent. It is submitted that it is contrary to law to reject appellant's claims on the attenuated theory of modifying the structure of the Mock patent by the incorporation therein of structural elements of unrelated purposes from other patents relating to engines of different type, particularly when such incorporation would be inconsistent with the teachings of the Mock patent.

Moreover, even the synthesis, by such incorporation of structural features from different patents, of a structure which could be used to practice appellant's method, would not properly anticipate appellant's invention. As this Court said in *Hartford-Empire Company* v. *Coe,* 66 App. D. C. 344; 87 F(2d) 741, quoting from *In re Moulton,* 40 App. D. C. 160:

> "It is also true, as contended by appellants, that a process is not anticipated by a prior mechanism by which, with some alterations it might have been performed. It is not only necessary that the prior patents might have been used to carry out the process, but that such use was either contemplated or would have occurred, in the ordinary mechanical operation of the device."

Appellant's expert witnesses, Dr. Conta and Mr. Brush, are men of integrity and of unquestionable reputation in the automotive engine field. They are not the kind of people who would lightly commit themselves to unequivocal statements that appellant's invention was a highly valuable contribution to the internal combustion engine art and that it was not even suggested by the prior patents, unless these statements represented their firm professional opinions. Their testimony is therefore entitled to the most serious consideration and the highest weight. So considered, there can be no doubt that the decision of the Patent Office is "clearly erroneous" under the rule laid down by this Court in the *Standard Oil Development Company* case, *supra.*

CONCLUSION

It is earnestly submitted that the additional evidence submitted on behalf of appellant in the District Court establishes beyond any reasonable doubt that the decision of the Patent Office in refusing appellant a patent on his invention was clearly erroneous.

This evidence establishes not only the great practical value of the invention, as to which no evidence was available before the Patent Office tribunals, but also establishes the clear error of the Patent Office tribunals in interpreting and applying the disclosures of the prior art patents.

WHEREFORE, appellant urges that the judgment of the District Court be revised and reversed.

Respectfully submitted,

Harold T. Stowell,
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BRIEF FOR APPELLEE

United States Court of Appeals

FOR THE DISTRICT OF COLUMBIA CIRCUIT

APPEAL NO. 10631

NEIL O. BRODERSON, APPELLANT
v.
JOHN A. MARZALL, COMMISSIONER OF PATENTS,
APPELLEE

APPEAL FROM THE JUDGMENT OF THE UNITED STATES DISTRICT COURT FOR THE DISTRICT OF COLUMBIA

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United States Court of Appeals
For the
District of Columbia Circuit

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Joseph W. Stewart
CLERK

STATEMENT OF QUESTION PRESENTED

In the opinion of appellee, the question is correctly stated by appellant.

United States Court of Appeals
FOR THE DISTRICT OF COLUMBIA CIRCUIT

APPEAL NO. 10631

NEIL O. BRODERSON, APPELLANT
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JOHN A. MARZALL, COMMISSIONER OF PATENTS,
APPELLEE

APPEAL FROM THE JUDGMENT OF THE UNITED STATES DISTRICT COURT FOR THE DISTRICT OF COLUMBIA

BRIEF FOR THE COMMISSIONER OF PATENTS

INTRODUCTION

This is an appeal from the judgment (App. 19) of the United States District Court for the District of Columbia dismissing the complaint (App. 2) in an action under Section 4915 R. S. (35 U. S. C. 63), in which appellant, as the applicant in an application for patent (App. 119) entitled "Method of Operating Internal Combustion Engines," Serial No. 442,830, filed May 13, 1942, sought to have the Court authorize the issuance to him of a patent containing claims 1 to 9, inclusive, of said application. The refusal of the claims by the Patent Office and the District Court was based on lack of patentability in view of cited prior art.

APPELLANT'S APPLICATION

Appellant's alleged method invention is described with reference to two rather diagrammatic showings, Figs. 1 and 2 (App. 146), and Fig. 4 (App. 147), of one-cylinder, four-cycle, internal combustion engines.

The engine shown in Figs. 1 and 2 includes a "main combustion zone" 6, overlying piston 2 (App. 125, final paragraph). Within an offset wall 3, appellant provides what he calls at one point in his specification (App. 125, final paragraph), "an auxliary combustion zone 5," and in the claims (see claim 1, App. 137 and 138), "an auxiliary combustion chamber communicating with the main combustion chamber through a restricted passage." In his specification, appellant asserts (App. 125, final paragraph) that "intake valve 7 is provided for the admission of air or a mixture of air and fuel during the induction stroke of the piston, and this valve is timed to operate as is conventional in four-cycle engines." "Exhaust valve 8," appellant adds, "is positioned in the cylinder head over the piston and it also operates conventionally to permit egress of the products of combustion on the exhaust stroke." Ignitor, or spark plug 9, extends into the auxiliary combustion zone or chamber to ignite the fuel-air mixture therein either at or near (see Graph of Operation, Fig. 3, App. 146) top dead center of the piston between the compression stroke and the power stroke. A fuel injector 10 for "spraying fuel or a rich mixture of fuel and air into the auxiliary combustion zone 5" may be located in wall 3, but it also may otherwise be located (App. 125, final paragraph; App. 137, second paragraph). In this connection, appellant, in his specification (App. 126, third paragraph), makes the following statements:

> The fuel injector need not be positioned as shown so long as it is positioned to inject fuel into the auxiliary combustion zone. For example, it may be placed at the necked-down juncture of the main combustion zone and the auxiliary combustion zone or it may be situated in the side wall of the main combustion zone and directed at the auxiliary combustion zone across the main combustion zone.

Appellant indicates (App. 123, final paragraph) that his auxiliary combustion chamber 5 has "a volume not substantially exceeding the volume of the main combustion chamber at top center position of the piston and preferably from 10% to 50% of the volume of the total combustion space at top center position of the piston."

The graph, Fig. 3 (App. 146), of the operation of appellant's one-cylinder, four-cycle engine illustrated by Figs. 1 and 2, shows the manner in which the charges of fuel may be controlled and varied. When the engine is idling, under little or no load, the fuel is injected entirely during the compression stroke of the piston, starting at a point I and stopping at a point I′. Appellant states (App. 127, first paragraph) that "Substantially all the fuel so injected remains in the auxiliary combustion zone due to the inrush of air from the main combustion zone." "The main combustion chamber," he adds, "contains substantially only air." With increasing load, the time when the injection of fuel is started is advanced to begin during the intake stroke of the piston. Under full load operating conditions, injection of fuel apparently may commence at point II during the intake (induction or suction) stroke of the piston, and continue until the compression stroke has begun, as at point II′ (App. 127, final paragraph). More specifically (App. 128, final paragraph), the injection of fuel is so timed, under full load operation, that one-half of the fuel is introduced on the intake stroke of the piston and the remaining half on the compression stroke. As appellant suggests (App. 137, fourth paragraph), devices exist, such as the "American Bosch primer," to which his witness Rolfsen referred (App. 23 and 24), to vary the duration of injection and the time of starting the injection of fuel. Substantially constant charges of air are admitted to the combustion space during the suction stroke (App. 123, final paragraph).

As a preface to his statement (App. 134, second paragraph) that, in general, "fuel supplied on the intake stroke is uniformly distributed throughout both spaces of the combustion chamber while fuel injected on the compression stroke is substantially completely retained in the auxiliary combustion zone," appellant asserts (App. 134, first paragraph) that, in practice, "a sharp boundary of demarkation between the mixtures in the main and auxiliary combustion spaces is not obtained," but that "a zone exists between the two spaces in which the transition between the mixture strengths is rather gradual." Again, appellant asserts (App. 134, second paragraph) that "this distribution may be somewhat modified in practice due to the many possible forms of double-spaced combustion chambers, the positioning and operation of the intake and exhaust valves, the location of the fuel injecting nozzle, and other factors."

In referring in his specification to part load operation, appellant asserts (App. 130, first paragraph; see also App. 126, first paragraph) that "Throttling may be employed to reduce the amount of air taken into the cylinder as the amount of fuel is reduced, but such throttling, by reducing the volume of air in the cylinder, necessarily results in a correspondingly low compression and greatly reduces the efficiency of conversion of the heat energy into useful work."

In the engine illustrated in Fig. 4 (App. 147), seemingly offered by appellant as showing a second of the "many possible forms of double-spaced combustion chambers" with which his method might be practiced, provision expressly is made (App. 134, final paragraph) for admitting air or air-fuel mixtures both to the auxiliary combustion chamber 17 and to the main combustion chamber 14, with which it communicates through passage 18. The main combustion chamber 14 includes an offset portion in which is a main intake valve 15. The auxiliary cylinder head 16, which provides the auxiliary combustion chamber 17, also includes the auxiliary intake valve 21, together with the fuel injection nozzle 19 and spark plug 20. "When air-fuel mixtures are admitted to the combustion chamber during the intake stroke through the intake valves," appellant asserts, "both main intake valve 15 and auxiliary intake valve 21 are preferably connected to a common manifold leading from a suitable air and fuel mixing device." Fig. 5 (App. 147) is a graph showing the relation of fuel feed to piston position in the operation of the engine illustrated by Fig. 4 (App. 123, third paragraph; App. 136, penultimate paragraph).

Appellant emphasizes in his specification (App. 122, second paragraph *et passim*) that an object of his method of operating a four-cycle internal combustion engine is to reduce the tendency of the engine to detonate or "knock."

PRIOR PATENTS RELIED UPON BY APPELLEE

The Werner Patent

The Werner patent, No. 1,616,157 (App. 101), discloses, as the Board of Appeals and the District Court indicated (App. 167, ante-penultimate sentence; App. 16, first paragraph; App. 18, final paragraph), an internal combustion engine which combines Otto cycle and Diesel cycle operation (see App. 104, lines 9 to 32). As shown in Fig. 1 (App. 101), which may be compared with appellant's Fig. 4 (Cf. Appellant's Brief, page 39, first paragraph), this patented engine comprises a (main) "combustion chamber" R (App. 104, line 12) and another (auxiliary or "ignition") chamber K, also called a "retort" (App. 104, line 3). Retort K, which is small, is in constant communication with larger chamber R through passages 20 and 21, the former of which is definitely restricted. An injector N sprays fuel into chamber R and an auxiliary carburetor M, which may be used in lieu of auxiliary injector N′, introduces a carburetted mixture of fuel and air into retort K (App. 105, lines 58 to 81).

Extending into retort K is a spark plug S to ignite the mixture of fuel and air therein (App. 105, lines 105 to 108).

Werner specifically discloses (App. 105, lines 69 to 75) that air is sucked into chamber R during the suction stroke of piston D. Such constant charges of air are compressed during the compression stroke of said piston (App. 105, lines 82 to 89). Supply of charges of fuel varied in amount is accomplished through carburetor M and injector N. As Werner states (App. 104, lines 33 to 37), he provides "controls for the admission or injection of fuel, including controls for a total amount, its timing, and the proportioning of the amounts introduced before and after initial ignition." Fuel is expressly injected during the compression stroke (App. 105, lines 90 to 95). The mixture in chamber R is "too lean to be ignitable by ordinary means," but the flaming gases from retort K will ignite it (App. 105, lines 108 to 125). Because "of the average leanness of the mixture," Werner recites (App. 105, lines 130 to App. 106, line 3), "the likelihood of fuel knock will be overcome."

The Mock Patent

The patent to Mock, No. 2,142,280 (App. 97), again discloses a four-cycle internal combustion engine. In Figs. 1 to 4 (App. 97), that patent, as interpreted by the Board of Appeals (App. 166, final paragraph) and the District Court (App. 15, final paragraph; App. 17, final paragraph), shows (1) a main combustion chamber, within the space bounded by the top of piston 9, on one side, and the bottom of the cylinder head, on the other side, and inclusive of the "restricted opening 16," and (2) an auxiliary combustion chamber 15, communicating with the main combustion chamber through said opening 16. A similar, if not better showing, akin to that of appellant's Fig. 4 (App. 147), is made in Figs. 6 and 7 of this same patent, with respect to an L-head engine (App. 98, second column, lines 30 and 31; App. 99, second column, line 71 to App. 100, first column, line 6; App. 134, final paragraph, particularly third sentence). Extending into chamber 15 are two spark plugs 20 and 21, and an injection nozzle 18.

Mock expressly discloses (App. 99, second column, lines 34 to 36) that air, indicated by crosses 25 (Fig. 3, App. 97), is drawn into the entire combustion space during the suction stroke of piston 9. As indicated in Fig. 3, such constant charges of air are compressed during the compression stroke of the piston. Mock asserts (App. 99, first column, line 68 to second column, line 5), with reference to the form of his invention illustrated in Figs. 1 to 4, that "fuel may be injected into chamber 15 through the nozzle 18 during the late exhaust or early intake strokes of the piston, the requirement being that the fuel must not enter too greatly into the piston displacement chamber." Mock adds that it may "be desirable to inject a portion of the fuel charge insufficient of itself to propagate combustion, early in the cycle, as for example during the intake stroke, and then inject the remainder of the fuel charge just prior to ignition," which is to say, during the compression stroke. Dots 24, in Fig.

3 (App. 97), show the presence of fuel vapor in the piston displacement chamber (or main chamber) during the compression stroke of piston 9, and fuel injection expressly may occur during said compression stroke (App. 99, second column, lines 69 to 70). A rich combustible mixture of fuel and air surrounds the spark plugs 20 and 21, and there is a leaner mixture elsewhere in the combustion space (App. 99, second column, lines 37 to 69), to the end of eliminating detonation (App. 100, first column, lines 20 to 32; App. 98, first column, lines 16 to 51).

British Patent No. 373,647

The British patent, No. 373,647 (App. 114), was and is relied upon solely as showing, in common with the Werner patent, an auxiliary combustion chamber which is not larger than the main combustion chamber. Said British patent specifies (App. 116, lines 96 to 102) that the "volume of the ante-chamber is preferably substantially equal to the clearance volume of the combustion space in the engine cylinder."

SUMMARY OF ARGUMENT

1. Review of the decisions of the Patent Office and the District Court involves consideration of appellant's specification, appellant's claims, and the patents cited by appellee.

2. The steps, conditions, and advantages which appellant would emphasize now as essential and critical in his method of operating an internal combustion engine were and are not so indicated in his specification.

3. Like his specification, appellant's claims are broad and sweeping, and do not differentiate with the requisite clarity and precision from the prior patents cited by appellee.

4. As the District Court expressely decided, the evidence adduced by appellant below did not in any way affect the conclusion reached by the Board of Appeals as to the unpatentability of the claims in suit.

ARGUMENT

1. Determination of the correctness of the decisions of the Board of Appeals and the District Court necessarily requires not only consideration of the evidence submitted by appellant at the hearing below, but also recourse to his specification, to his claims, and to the teachings of the three patents cited by appellee.

2. Recourse to appellant's specification is requisite under Section 4888 R. S. (35 U. S. 33) and old Rule 35 of the Rules of Practice of the United States Patent Office, as in force when appellant's application was filed, to ascertain what steps, conditions, and advantages were denominated by appellant at the governing time of the filing of his application (*Abbott et al.* v. *Coe,* 71 App. D. C. 195, 109 F. 2d 449; *In re Pollack et al.,* 36 C. C. P. A. 1156; 175 F. 2d 587) as essential to his method of operating an internal combustion engine, and which were recited by him as preferable and hence not critical. *In re Gardiner,* 36 C. C. P. A. 748, 171 F. 2d 313, and case cited.

In the words of the Board of Appeals (App. 165), Fig. 1 (App. 146) of appellant's application drawings shows the main combustion chamber 6 and the auxiliary combustion chamber 5 separated by "a slight restriction," though appellant manages to describe the engine illustrated by that figure (Cf. App. 125, final paragraph) without referring to any restriction. But certainly, that restriction is by no means as marked as appellant's Exhibits Nos. 2, 3 and 4 would suggest, and Dr. Conta's testimony on cross-examination (App. 62 to 65) indicates the inaccuracy of these charts. Again, while appellant's specification (App. 134, second paragraph) does, to repeat, disclose that, in general, "fuel supplied on the intake stroke is uniformly distributed throughout both spaces of the combustion chamber while fuel injected on the compression stroke is substantially completely retained in the auxiliary combustion zone," it does not recite, as "the very heart of the invention in this case" (Cf. Appellant's Brief, page 46; App. 28; App. 49, final question and answer; App. 71 and 72), the obtaining of "two homogeneous mixtures of different degrees of richness in two different chambers," nor ascribe such an alleged vital result to the restriction (Cf. App. 42, final question and answer). On the contrary, appellant's specification contains, consistently with the testimony of appellant's witness, Rickard, on cross-examination (App. 32), statements, as earlier quoted, that there is no sharp boundary of demarcation between the mixtures in the main and auxiliary combustion spaces.

From the quoted and other portions of appellant's specification, it would appear that the alleged advantages of appellant's method are secured when a rich mixture is maintained at the locus of the ignitor or spark plug, with a leaner mixture elsewhere in the combustion chamber. Such is the tenor of the statement in appellant's specification (App. 129, final paragraph) that "A relatively rich mixture is maintained in the vicinity of the ignitor to assure ready combustion while a relatively lean mixture exists in the rest of the combustion chamber remote from the ignitor to discourage detonation." Such also is the indication of cancelled claim 10 (App. 145), which was rejected by the examiner, along with claims 1 to 9, but which was withdrawn by appellant at the hearing of his appeal before the Board of Appeals (App. 148; App. 166, first paragraph). As a definition of appellant's method, said claim 10 called for "injecting into a portion of said combustion space during the compression stroke of the piston controlled portions of said charges of fuel varied in amount in predetermined relation to the quantity of fuel supplied to effect a controlled segregation of fuel in said portion of the combustion space effective to provide in said portion of the combustion space an ignitable fuel mixture." Claim 10, moreover, defines appellant's method without reference to any "restricted passage."

Such an analysis of appellant's specification as the foregoing leads inevitably, it is submitted, to the conclusion reached by the examiner (App. 156, second paragraph) that the "real gist and point of the alleged invention appears to reside in the proper timing of the fuel injection period so as to insure an ignitable mixture at the spark plug at all load conditions and properly proportioned mixtures in the main and auxiliary combustion chambers so that the remainder of the fuel charge will burn without knocking."

The teaching of appellant's specification (App. 123, final paragraph) that, "preferably," the auxiliary chamber should have "from 10% to 50% of the volume of the total combustion space at top center position of the piston" is not at odds with such a conclusion. As appellant's witness, Dr. Conta, asserted (App. 42), size of the two combustion chambers is of importance only in that "In order for the engine to run at all, an ignitable mixture must be present at the spark plug."

On the other hand, for Broderson now to characterize (Cf. Brief, pages 14 and 15) his method of operating an internal combustion engine as one in which "air is drawn into the combustion space substantially unthrottled under all conditions of operation," is for him to fly in the face of the opposing teachings in his specification (App. 130, first paragraph; App. 126, first paragraph), already mentioned.

3. The narrow aspect which appellant belatedly would cast on his method is not recited in his claims, any more than it is expressed in his specification. Like the appellants in *Gilbert et al.* v. *Marzall,* 86 U. S. App. D. C. —, 182 F. 2d 389, 85 USPQ 288, Broderson has phrased his claims in language that is too broad. He has restated the prior art without setting forth his own distinctive contribution, if any, with clarity and precision. Representative claim 1 will, it is submitted, read upon the described engine of the Werner patent as operated with carburetor M.

If there be any possible doubt as to claim 1 so reading, by reason of the fact that a carburetted mixture of fuel and air, rather than fuel alone, is introduced by Werner through carburetor M, even though appellant, himself, optionally injects fuel or fuel and air (App. 125, final paragraph; App. 137, second paragraph), there should be no doubt that this claim reads on said Werner engine as operated with fuel injector N′. Werner specifies (App. 107, lines 3 to 15) that through injector N′ "a small portion of fuel can be injected into the retort toward the end of the compression stroke." The Board of Appeals (App. 167 and 168) has applied claim 1 to the Werner patent, in detail.

Consistently with the broad sweep of the disclosure of appellant's specification, such a claim as claim 1 does not require "homogeneous" charges, of fuel and air, in the main and auxiliary combustion chambers, as appellant would suggest (Brief, page 37). It calls merely for a "controlled stratification of the fuel between the auxiliary combustion chamber and the main combustion chamber." In the Werner engine, fuel in the retort K and fuel in the chamber R are necessarily so stratified, and such stratification is, of course, controlled. Again, while Werner may use two injection nozzles, as appellant asserts (Brief, pages 37 and 38), so may appellant, in operating his engine shown in Fig. 4 (App. 147), admit air-fuel mixtures through both of the intake valves 15 and 21 (App. 134 and 135), and appellant's claims, agreeably therewith, hence nowise exclude the use of two injection nozzles. The timing of the supply of fuel in the Werner engine, as hereinbefore explained, satisfies the requirements of the claims. In sum, none of the differences that appellant would draw between his method and the method of operation of the Werner engine are recited in the claims on appeal.

As indicated by the ruling of the Board of Appeals (App. 168) and the finding of the District Court (App. 19), proportioning the fuel injected during the various periods of the cycle to avoid detonation is a matter of adjustment well within the scope of the skilled mechanic. Such, further, is the tenor of the decision of the Court of Customs and Patent Appeals in the case of *In re Saurer* (28 C. C. P. A. 1021, 118 F. 2d 719), which the examiner cited and quoted (App. 163).

Neither the patent to Werner nor the patent to Mock is impertinent because of purporting to cover an internal combustion engine. In both, the mode of operation is sufficiently spelled out, to render the patents effective against the method claims under review (*Ex parte Wilson,* 345 O. G. 3, 1926 C. D. 27, affirmed by the Court of Appeals of the District of Columbia, *In re Wilson,* 345 O. G. 5, 1926 C. D. 134, 56 App. D. C. 400, 8 F. 2d 1016).

The Board of Appeals and the District Court concurred in holding (App. 166 and 167; App. 18) that such a representative claim as appellant's claim 1 is unpatentable over the patent to Mock in view of the patent to Werner and British patent No. 373,647. The reiterated position of appellant and his witnesses (Appellant's Brief, page 30 *et passim;* App. 45 and 46; App. 82 to 86) is that the Mock patent discloses only one combustion chamber. The Board and the District Court ruled (App. 166 and 167; App. 15 and 16; App. 17 and 18) that the Mock engine includes two combustion chambers, and an examination of either Fig. 4 or Fig. 6 of the Mock patent suffices to demonstrate the soundness of that ruling. Making reference to the Werner patent and British patent No. 373,647, the Board and the District Court also agreed (App. 167; App. 18) that there would be no invention in applying the process disclosed in the Mock patent to an engine in which the auxiliary combustion chamber is not larger in volume than the main combustion chamber. With the Mock process as with appellant's method, the whole gist and point is the timing of the fuel injection period so as to insure an ignitable mixture at the spark plug at all load conditions and properly proportioned mixtures in the main and auxiliary combustion chambers so that the remainder of the fuel charge will burn without knocking. To borrow appellant's own language from his specification (App. 129, final paragraph), the "advantage of operating at full load with two different mixture strengths in a common combustion chamber is that detonation is obviated or at least minimized." Also, as appellant continues, a "relatively rich mixture is maintained in the vicinity of the ignitor to assure ready combustion while a relatively lean mixture exists in the rest of the combustion chamber remote from the ignitor to discourage detonation."

If there be some significance in the limitation of claims 3, 4, 5, 6 and 8 that the air enters "at least in part through" the auxiliary combustion chamber, a feature which is stressed in appellant's brief (Cf. page 47) rather than in his specification, wherein appellant asserts (App. 123, final paragraph; but also see App. 134, second paragraph) that "preferably" at least a part of the air is admitted through the auxiliary combustion chamber, then it suffices to note that this feature is shown in Fig. 6 of the Mock patent, as the Board explained (App. 173).

4. From the foregoing, it will appear that the evidence offered on behalf of appellant is not of such scope and weight as clearly and convincingly to show that the method described by appellant in his specification and defined in his claims is not disclosed in or suggested by the prior patents which appellee cited. The professed superiority of appellant's method has nowise been proved. Comparative tests were not performed by appellant, and hence the record now made, like the record before the Board of Appeals, fails to "establish that the method disclosed in the application on appeal can maintain high efficiencies at low power demands to an extent not attainable by the methods disclosed in the prior art" (App. 172). The construction of the so-called "Broderson Test Engine" is not spelled out with any exactness in the testimony, nor shown by photographs or drawings, and specific test data was not offered by appellant. All in all, the District Court manifestly was warranted in finding (App. 16; App. 19) that the testimony introduced at the trial does not in any way affect the conclusion reached by the Board of Appeals as to the unpatentability of appellant's claims in suit.

CONCLUSION

For the reasons given, it is respectfully submitted that the findings of fact entered by the District Court receive adequate support in the record, that the conclusions of law are correct, and that the judgment appealed from should, therefore, be affirmed.

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Clarence W. Moore, *of Counsel.*

September 1950.

U. S. GOVERNMENT PRINTING OFFICE: 1950

No. 10,631

REPLY BRIEF FOR APPELLANT

United States Court of Appeals

For the District of Columbia Circuit

Neil O. Broderson, *Appellant,*

vs.

John A. Marzall, Commissioner of Patents, *Appellee.*

Appeal from the United States District Court
for the District of Columbia

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United States Court of Appeals

FOR THE DISTRICT OF COLUMBIA CIRCUIT

Appeal No. 10,631

NEIL O. BRODERSON, *Appellant*,

vs.

JOHN A. MARZALL, Commissioner of Patents, *Appellee.*

Appeal from the United States District Court for the District of Columbia

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REPLY BRIEF FOR APPELLANT

The errors of fact and misunderstandings to be found in the brief filed on behalf of the Commissioner of Patents, appellee, illustrate and emphasize the superficial treatment and lack of understanding which appellant's application for patent has received in the Patent Office. Because these errors and misunderstandings relate to matters vital to the consideration of the issues in this appeal and to the understanding of appellant's invention and its novel contribution to the internal combustion engine art, it is felt necessary to discuss them in this reply brief.

There Is No Throttling of Air Intake in Appellant's Method of Operation

A particularly serious misunderstanding is shown by appellee's discussion of the matter of throttling.

On page 13 of the brief appellee states that "for Broderson now to characterize his method of operating an internal combustion engine as one in which 'air is drawn into the combustion space substantially unthrottled under all conditions of operation' is for him to fly in the face of the opposing teachings in his specification". In support of this utterly erroneous contention appellee quotes on page 5 of his brief a statement from the Broderson application which obviously relates *not* to the method of the invention but to the operation of "conventional induction type engines".

To eliminate any possibility of doubt as to this, we quote here the *entire* paragraph from which counsel for appellee has abstracted one sentence:

> "In conventional induction type four-cycle engines, which induce a preformed air-fuel mixture from a carburetor or the like, reducing the amount of fuel without reducing the amount of air results in creating a leaner mixture. Therefore, if only 5 parts of fuel is added to 150 parts of air for low power output, a mixture of 30 to 1 results, which is too lean to ignite satisfactorily, if at all. Throttling may be employed to reduce the amount of air taken into the cylinder as the amount of fuel is reduced, but such throttling, by reducing the volume of air in the cylinder, necessarily results in a correspondingly low compression and greatly reduces the efficiency of conversion of the heat energy into useful work." (App. 130)

Only the most superficial reading of the application coupled with a lack of understanding of the subject could have lead to such an egregious error particularly in view of the fact that both in the specification and the claims appellant has clearly and unequivocally stated that in his method of operation the air is unthrottled.

See, for example, the statement, almost at the beginning of the specification:

> "In my method of operating an internal combustion engine, air is drawn into the combustion space substantially unthrottled under all conditions of operation." (App. 121)

And note that all of the claims presented in this application include in the very first clause after the word "comprising" the limitation "admitting constant charges of air to the combustion space of the engine.

The Two Combustion Zones

Counsel for appellee has tried to make a point out of the variation in amount of restriction between the auxiliary chamber (5 in the application drawing, App. 146) and the main combustion chamber (6 in the application drawing), pointing out that the restrictions appear somewhat sharper in the charts (Exhibit Nos. 2, 3 and 4), and professes to find some comfort in the fact that both the Broderson specification (App. 134) and appellant's witness, Rickard, on cross-examination state that there is no sharp boundary of demarcation between the mixtures in the main and auxiliary combustion spaces.

This lack of a sharp boundary between the two zones, however, does not have the slightest effect on the principles of operation of the invention nor has appellee attempted to point out such an effect. The "heart of the invention" is the provision of a mixture in the auxiliary combustion space which is ignitable under all conditions of operation, while the composition of the mixture in the main combustion space varies with varying power demands in such a manner that the air charged to the engine remains constant or "unthrottled" at all times. This variation in composition of the mixture in the main combustion space while maintaining a relatively constant mixture (within the limits of ignitability) in the auxiliary combustion space is graphically illustrated in Fig. 6 of the drawing of the Broderson application (App. 147). None of these conditions require, as both the specification and appellant's expert witness make clear, that the boundary between the zones be "sharp". It is sufficient, and *novel,* that there be two definite spaces in the combustion chamber, in one of which an ignitable mixture is maintained and ignition is effected while in the other a mixture, varying with the load on the engine is secondarily burned by the combustion of the ignitable mixture in the first space.

The Werner Patent

In discussing the Werner patent (brief for appellee pages 6 and 7), counsel discreetly fails to mention the critical fact that in operation of the Werner patent introduction of fuel is continued *after* the beginning of ignition thereby introducing Diesel cycle type of combustion. (App. 104, lines 9-20). Whereas, in the Broderson method all of the fuel is injected in an entirely different portion of the cycle, beginning before or at bottom dead center of the intake stroke, continuing into part of the compression stroke but ending before ignition. Under all conditions of operation, Broderson's entire fuel charge is introduced before ignition takes place. (App. 106, lines 31-36).

Broderson's method alters the Otto cycle by using constant charges of air under varying load conditions thereby obtaining greater efficiency, but he retains the characteristic feature of the Otto cycle that all of the fuel is introduced prior to ignition.

The Werner operation, on the contrary, is a Diesel operation with varying amounts of auxiliary pre-ignition fuel, which may be nil, superimposed on the typical Diesel operation.

The Mock Patent

Counsel for appellee is clearly in error in continuing to insist, in spite of the unequivocal and uncontroverted testimony of appellant's expert witnesses (Conta, App. 45-46; Brush, App. 82-86), that the engine of the Mock patent has two combustion spaces.

Moreover, the error of the contention can be determined by any inspection of the drawings of the Mock patent which is more than superficial. It will be clear that in Fig. 2 of the Mock patent, for example, (App. 97) if the connecting rod were in vertical position (top dead center of the stroke) the piston ~~rod~~ would be raised to within the normal mechanical clearance of the cylinder head leaving only *one* combustion space at top dead center as shown in Mock's patent, Fig. 4.

British Patent 373,647

There is no mention in counsel's short reference to British patent 373,647, that this patent relates solely to an addition to the Diesel type engine in which the fuel is burned as it enters the combustion space during a substantial portion of the power stroke. No mention is made that the "ante-chamber" is a hot bulb in which the fuel is ignited as it enters the combustion space. The British patent merely discloses a device for increasing the amount of heat available for vaporizing and igniting the difficultly vaporizable fuel used in Diesel engines which engines depend upon the heat of compression of the air in the combustion space for ignition of the fuel charge as it enters the combustion space. Nowhere in the brief for appellee is there any suggestion as to how this hot-bulb construction in a Diesel engine could possibly teach the new method of operation of Otto cycle engines described and claimed by appellant.

Summary

The misunderstandings and misreadings of both the Broderson application and the cited prior patents illustrated above is typical of the errors and superficiality of treatment which has forced appellant to come to this Court seeking the serious judicial consideration of his inventive contribution which it is clear he has not heretofore been granted.

Respectfully submitted,

Harold T. Stowell,
Attorney for Appellant.

No. 10,631

BRIEF AS AMICUS CURIAE

United States Court of Appeals

FOR THE DISTRICT OF COLUMBIA CIRCUIT

United States Court of App
For the
District of Columbia Circu
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NEIL O. BRODERSON, *Appellant*,

vs.

JOHN A. MARZALL, Commissioner of Patents, *Appellee*.

Appeal from the United States District Court for the District of Columbia

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United States Court of Appeals

FOR THE DISTRICT OF COLUMBIA CIRCUIT

Appeal No. 10,631

NEIL O. BRODERSON, *Appellant*,

vs.

JOHN A. MARZALL, Commissioner of Patents, *Appellee*.

Appeal from the United States District Court for the District of Columbia

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BRIEF AS AMICUS CURIAE FOR UNIVERSITY OF ROCHESTER

THE UNIVERSITY OF ROCHESTER, an educational institution incorporated under the laws of the State of New York and located at Rochester, Monroe County, New York, being convinced of the importance to the public welfare of the invention involved in this appeal and being particularly cognizant of the potential value of the invention because of tests carried out by members of its faculty in the Mechanical Engineering laboratories of the University, desires to express its views as an aid to this Court in the consideration of the issues involved in the appeal.

The presentation of its views is particularly needful because it appears from the record and briefs that neither the Patent Office nor the District Court have comprehended the novelty or appreciated the importance of the Broderson invention.

The Importance of the Invention

It was the importance of the improvements in the operation of engines of the Otto cycle type which were claimed for the Broderson invention that motivated the University in authorizing and supporting the tests carried out in its laboratories. Improvement in the efficiency of the Otto cycle engine at less than maximum power demands and improvement in the ability of the Otto cycle engine to use efficiently the lower grade fuels are constant and continuing goals of the automotive profession.

Documentation of the importance of the invention is found in two recent articles in publications of wide circulation. In the August 1950 number of Fortune at page 20 and in the September 1950 number of Nation's Business at pages 50, 52 and 53 are discussions of a new engine said to be under development in the laboratories of The Texas Company. The stated advantage of the engine referred to in the articles—increased efficiency at low power demands and ability to use low grade fuels without knocking—are the advantages found to be provided by the Broderson engine in the tests in the University laboratories.

It is, of course, true that the Diesel type engine performs effectively with low grade fuels and has relatively high efficiencies at low power demands, but the Diesel engine operates on an entirely different principle from that of the Otto cycle engine and it achieves its results only at the expense of other disadvantages, which to date, and in the foreseeable future, have ruled it out of the passenger automobile field. It is the Otto cycle engine which powers our passenger automobiles today and it is the Otto cycle engine to which the Broderson invention is directed.

The Tests at the University

Tests of the Broderson invention at the University were carried out by Corwin Rickard, a graduate student and instructor in the Division of Engineering at the University (App. 26-27), under the direct supervision of Dr. Lewis Conta, Professor of Mechanical Engineering and now Chairman of the Engineering Division of the University (App. 33-35 and 61).

Professor Conta's conclusions as to the results of the tests were expressed by him at the trial substantially as follows:

> "(a) that the Broderson method was very advantageous over the conventional carburetor method with respect to detonation (App. 61);
> (b) that at any condition less than full load, the economy of the Broderson method of operation was substantially better than that for the carburetor operation (App. 61);
> (c) that such increase in economy would result in considerable fuel savings under the load conditions which are most commonly experienced in most automotive type engines (App. 61); and
> (d) that a poorer grade of fuel could be used by the Broderson method (App. 61)."

The Novelty of the Invention

The conclusions of the Patent Office and the District Court of the lack of patentable novelty in the Broderson invention and their position that this invention is taught or suggested by the cited prior patents are strangely in contrast with the published report (Nation's Business, l.c.) that several hundred thousand dollars had been spent by The Texas Company in attempting to solve the same problem.

The conclusions of the Patent Office and the District Court are also at variance with the considered opinion of Professor Conta (App. 43-61) arrived at after a thorough study of the Broderson invention and the cited prior patents.

It is noted that Professor Conta's conclusion that the Broderson invention is not taught by the prior patents was identical with the conclusion of a highly respected practical automotive engineer whose experience is almost coextensive with the history of the automobile in the United States, Mr. Alanson P. Brush.

Conclusion

In conclusion, it is urged that the importance of the advantages presented by the Broderson invention requires the most careful consideration of the issues of the appeal to the end that development of a contribution to the automotive industry of the greatest importance to our economy should not be discouraged by the unjustified refusal of a patent on the invention, and it is earnestly submitted that on the record before the Court in this appeal the refusal of the requested patent is unwarranted and erroneous.

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University of Rochester.